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Chemistry 30

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Thermochemical Changes

Unit A

Red Deer Catholic Regional Schools
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EDMONTON PUBLIC SCHOOLS
Calgary Board of Education
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Chemistry 30

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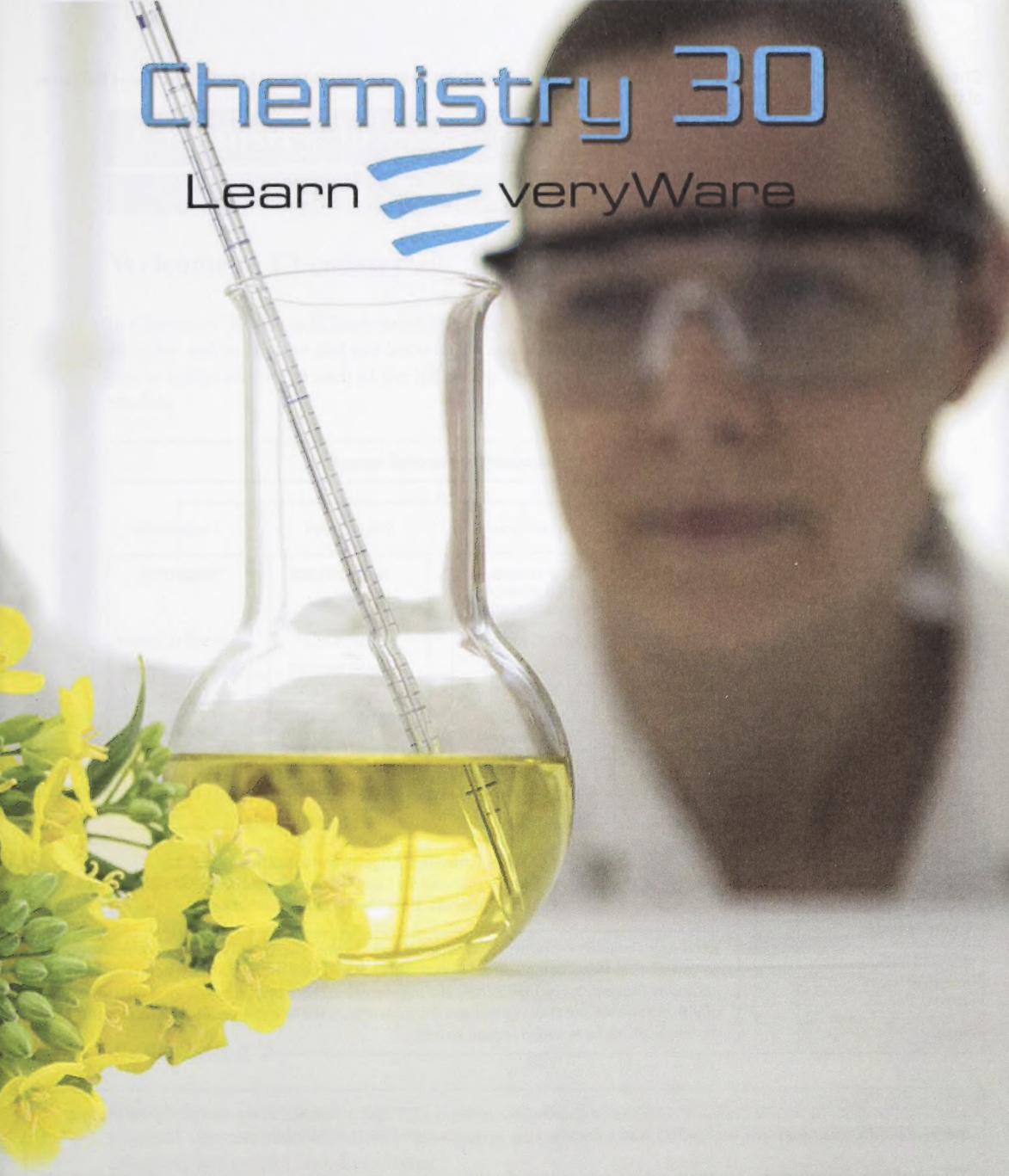

Thermochemical Changes

Unit A

Chemistry 30 was created by Alberta Education in partnership with the following educational jurisdictions under the terms of the *BCP Collaborative Course Development Project*:

- Black Gold Regional Schools
- Calgary Board of Education
- Edmonton School District No. 7
- Peace Wapiti School Division No. 76
- Pembina Hills Regional Division No. 7
- Red Deer Catholic Regional Division
- Rocky View School Division No. 41

Chemistry 30 Learn EveryWare
Unit A: Thermochemical Changes
Student Module Booklet
ISBN 978-0-7741-3174-2

Cover Art: © Sophia Winters/shutterstock

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Education, **http://www.education.gov.ab.ca**
- Learning Resources Centre, **http://www.lrc.education.gov.ab.ca**
- Tools4Teachers, **http://www.tools4teachers.ca**

Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

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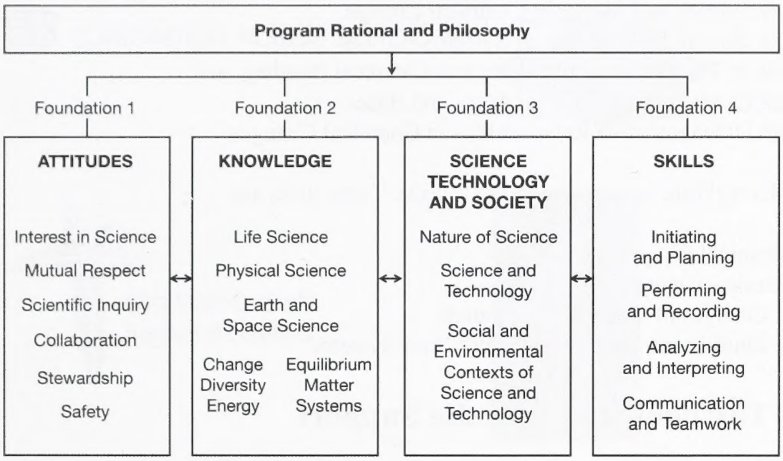
Chemistry 30

Welcome to Chemistry 30

In Chemistry 30 you will learn more than facts. You will be encouraged to develop positive attitudes and to acquire and use knowledge and skills in responsible ways. Your studies will lead you to achievements in each of the following four areas prescribed by the Alberta Program of Studies.



Foundation 1

Attitudes—*Students will be encouraged to* develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Foundation 2

Knowledge—*Students will* construct knowledge and understandings of concepts in life science, physical science, and Earth and space science and apply these understandings to interpret, integrate, and extend their knowledge.

Foundation 3

Science, Technology, and Society (STS)—*Students will* develop an understanding of the nature of science and technology, the relationships between science and technology, and the social and environmental contexts of science and technology.

Foundation 4

Skills—*Students will* develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

This course builds upon the scientific concepts from

Grade 7 Science, Unit C: Heat and Temperature
Science 8, Unit A: Mix and Flow of Matter
Science 9, Unit B: Matter and Chemical Change
Science 9, Unit D: Electrical Principles and Technologies
Science 10, Unit A: Energy and Matter in Chemical Change
Science 10, Unit D: Energy Flow in Global Systems
Chemistry 20, Unit A: The Diversity of Matter and Chemical Bonding and
Chemistry 20, Unit C: Matter as Solutions, Acids and Bases
Chemistry 20, Unit D: Quantitative Relationships in Chemical Changes

Chemistry 30 Learn EveryWare is composed of four units. These units are

Unit A: Thermochemical Changes
Unit B: Electrochemical Changes
Unit C: Chemical Changes of Organic Compounds
Unit D: Chemical Equilibrium Focusing on Acid-Base Systems

Chemistry 30 Textbook and Website Support

Nelson Chemistry, Thomson Nelson

You will be using *Nelson Chemistry* as your textbook for this course. It will help you add depth to your understanding of the topics you study. You will find additional support at the textbook's online website, http://www.science.nelson.com/. Here, you can use unit pre-quizzes, web links, chapter highlights, study tips, research tools, and other opportunities for further learning.

Chemistry 30 Partners

Alberta Education

Black Gold Regional Schools

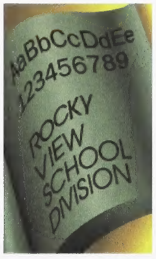
Calgary Board of Education

Peace Wapiti School Division No. 76

Edmonton Public Schools

Pembina Hills Regional School Division No. 7

Red Deer Catholic Regional Schools



Learning in an Online Environment

You can look forward to using resources, such as online newspapers and interactive multimedia, from the Internet for various activities. As a registered student, you will also have access to computer simulations, computer multimedia, computer graphics, and electronic information to support your learning.

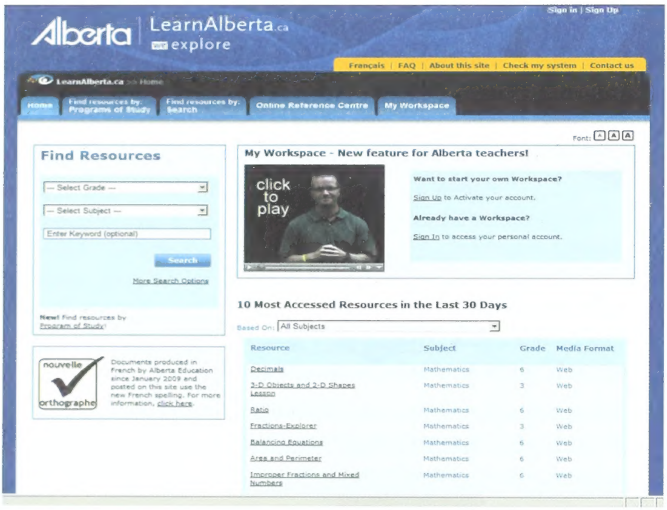
LearnAlberta.ca

LearnAlberta.ca is a protected digital learning environment for Albertans. This Alberta Education portal, found at http://www.learnalberta.ca/, is a place where you can support your learning by accessing resources for projects, homework, help, review, or study.

For example, LearnAlberta.ca contains a large Online Reference Centre that includes multimedia encyclopedias, journals, newspapers, transcripts, images, maps, and more. The National Geographic site contains many current video clips that have been indexed for Alberta Programs of Study. The content is organized by grade level, subject, and curriculum objective.

Use the search engine to quickly find key concepts. Check this site often as new interactive multimedia segments are being added all the time.

If you find a password is required, contact your teacher or school to get one. No fee is required.



Alternative Learning Environments and Distributed Learning

Distributed Learning is a model through which learning is distributed in a variety of delivery formats and mediums—print, digital (online), and traditional delivery methods—allowing teachers, students, and content to be located in different, non-centralized locations. Chemistry 30 Learn EveryWare students will be completing this course in a variety of learning environments, including traditional classrooms, online/virtual schools, home education, outreach programs, and alternative programs.

Instructional Design

Explanation

The learning model used in Chemistry 30 Learn EveryWare is designed to be engaging and to have you participate in inquiry and problem solving. You will actively interpret and critically reflect on your learning process. Learning begins within a community setting at the centre of a larger process of teaching and learning. You will be encouraged to share your knowledge and experiences by interaction, feedback, debate, and negotiation.

Components

This course uses the following structure and instructional design to connect you to the relevant curriculum and scientific concepts in Chemistry 30. These components are used consistently throughout the course and will help you in seeing the context and overall content of the program.

Big Picture

Big Picture provides a brief introduction to the module while connecting to your prior learning and personal knowledge. It refers to the essential questions of the module and invites you to reflect on the "big picture" within your own context.

Discuss

Discuss provides opportunities for you to interact with your peers and teacher. Discussion topics and collaborative activities should be independent of delivery mode, given the variety of technology access and delivery methods in schools.

Explore

Explore encourages you to investigate new concepts through preparation and presentation (Read), multimedia interactions (Watch and Listen), hands-on simulations (Labs), and explorative activities (Try This). Components within this section often do not follow a specific order. For example, you can do Watch and Listen after Try This or do Labs before Read.

Get Focused

Get Focused encourages you to focus on the task at hand and the outcomes to achieve.

Going Beyond

Going Beyond gives you the choice of challenging and enriching your knowledge beyond the lesson.

Lab

Labs include hands-on activities with available equipment/materials and/or multimedia simulations of a lab.

Lesson

Each lesson consists of the main learning content from which you explore, reflect, and connect. The length of each lesson is defined by content that covers at least one measurable outcome.

Module

Each module consists of content developed around a general or major outcome. Modules are comprised of lessons and include the introductory sections Big Picture, In This Module, and Module Summary and Assessment.

Read

The Read component uses textual material to convey concepts to you. This material may appear directly within this component. Alternatively, it may be presented indirectly through another resource. For example, you may be sent to your textbook or provided with a link to a website.

Reflect and Connect

Reflect and Connect provides you with opportunities to check your understanding of concepts introduced in the lesson (Self-Check) and to make connections to prior learning and personal knowledge (Reflect on the Big Picture). It also provides you with opportunities to interact with your peers and your teacher through communication and collaboration (Discuss).

Reflect on the Big Picture

Reflect on the Big Picture, part of Reflect and Connect, provides connections to the Big Picture introduced at the beginning of the module. It connects and adds to the initial essential question(s) and situates the concepts of the lesson within the Big Picture context.

Summary

There are course, unit, module, and lesson summaries. All lesson summaries build toward the unit and course summaries and make connections to the Big Picture introduced at the module level. Each summary provides you with information about what you have accomplished.

Self-Check

Self-Check provides you with opportunities to check your understanding of new concepts learned in the lessons and to make connections to prior learning. These may be in auto-marked form or may require teacher feedback.

Try This

Try This includes opportunities to practise and apply learned concepts outside of a lab environment. These can be simulations, questions, webquests, or other activities that provide you with a space to explore different ways of applying new concepts.

Unit

The units of study are identified in the Program of Studies. Units are defined by subject matter and are not limited by quantity of content or time of study. Each unit is comprised of modules (usually one for each general outcome), includes a general introduction and a visual representation of content structure (e.g., concept organizer/site map) as well as a list of general outcomes to be addressed, and includes a unit summary and assessment.

Watch and Listen

Watch and Listen includes both passive and interactive multimedia content (podcasts, videos, interactive Flash activities, etc...).

Visual Cues (Icons)

You will see icons throughout the course. These icons are clues regarding the type of activity you are about to begin.

Each unit in the course has a different colour theme, and the icons will change colour to match. For example, here are the four different colours of the Big Picture icon that appear in Units A to D, respectively.

Unit A

Unit B

Unit C

Unit D

The icons and their meanings are given.

Big Picture

Assessment

Summary

Get Focused

Read

Try This

Self-Check

Reflect and Connect

Explore

Reflect on the Big Picture

Going Beyond

Watch and Listen

Discuss

Lab

Special Learning Activities: Labs and Simulations

This course includes chemistry experiments for you to perform. To avoid the need for specialized apparatus and chemicals, you will be provided with computer multimedia simulations to provide a hands-on experience. For example, you will have the opportunity to use simulations to examine the boiling points and melting points of substances, the behaviour of gases under varying pressures and temperatures, and the solubility of a substance at various temperatures.

Reference (Data Tables)

In this course you will need numerical and scientific data for reference. Just inside the front cover of your textbook, *Nelson Chemistry*, is the periodic table of elements. In addition there are data tables at the very back of the textbook and in the textbook Appendices.

The Chemistry Data Booklet from Alberta Education also contains the reference data. You will be allowed to use a copy of the Data Booklet when writing the Chemistry 30 Diploma Examination. That is a good reason for becoming familiar with the Data Booklet. The Data Booklet can be downloaded from http://www.education.alberta.ca/admin/testing/diplomaexams.aspx.

Glossary

A chemistry glossary—an alphabetical list of chemistry terms and their meanings—is provided in this course. Your textbook, *Nelson Chemistry*, also has a glossary for you to refer to.

Lesson Answers (for students)

For many items, answers are provided in the appendix. Some items, especially assessment items, are to be marked by your teacher. For these items, submit your work to your teacher.

Using the Chemistry 30 Course Folder

The Chemistry 30 course folder serves as the organized collection of your work in Chemistry 30 Learn EveryWare. It exhibits to others your efforts, achievements, self-reflection, and progress throughout the course. When you want to show your friends or family what you've been learning, your work is all there.

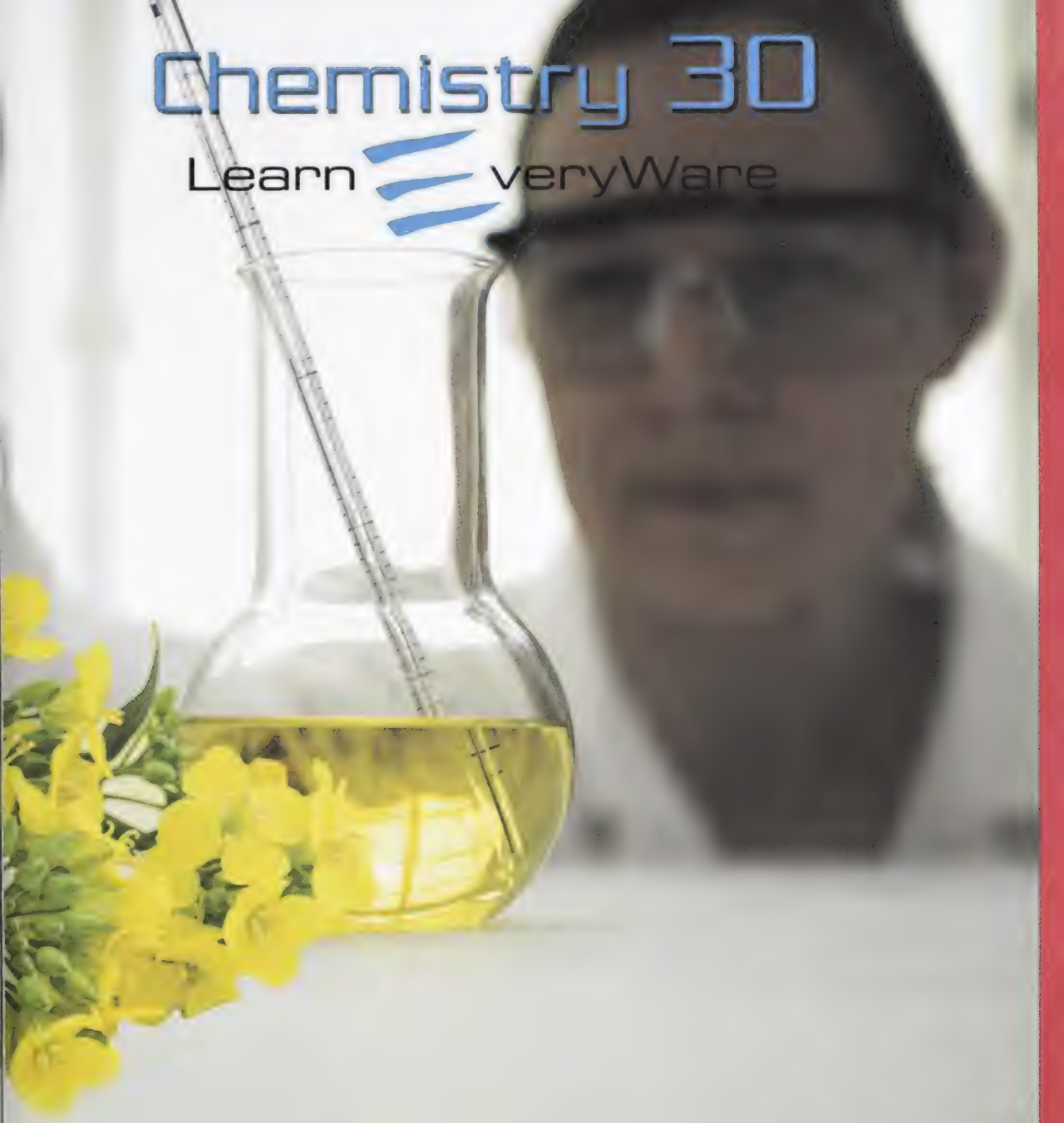
You will be expected to put all of your work into the course folder. If you are unsure of the process, your teacher will walk you through it. Throughout the course you will be asked to add things to the course folder.

In addition to being able to show others what you have done, the course folder lets you see your progress. It lets you see how your knowledge, skills, and understandings are growing. It also lets you review and annotate work you have already completed. You may find your course folder useful in preparing for tests and quizzes.

Periodically, you will be asked to share items from your course folder with your teacher. This is not always for grading, as often your teacher may use these items to learn more about you and your interests or as a way of tailoring other work assigned to you.

Chemistry 30

Learn EveryWare



Thinking Energy

Module 1

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Unit A Introduction

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Unit A studies the energy changes that occur in chemical reactions. In this unit you will learn how to measure the magnitude of such energy changes. You will also explore scientific theories that are used to predict and explain the energy changes involved in a chemical change, which are based on empirical measurements similar to the type you will make.

Module 1 examines how energy changes in chemical reactions are determined and interpreted. In Science 10 you used calorimetry to investigate energy changes of physical changes. In this module you will use calorimetry to measure enthalpy changes. You will use standard molar enthalpies of formation to predict the magnitude of energy changes associated with chemical reactions.

Module 2 investigates the events and energy changes associated with chemical reactions from the molecular level. You will learn about activation energy and the role that catalysts have to play in chemical processes. You will understand the function of catalysts from the perspective of chemical energetics.

Because energy is a unifying theme throughout this course and in science, these two modules will be an important foundation for your study throughout this course. For example, in Unit B you will investigate electrochemical changes and further study energy conversions when matter undergoes change. Unit C involves an investigation of hydrocarbons, a common source of energy in our society, and petrochemicals. Finally, Unit D involves a study of chemical equilibrium. As you will find, energy transfers between a chemical system and its surroundings can influence an equilibrium. The influence of energy in a chemical system is best exemplified by the many chemical processes that require energy in the form of heat or light in order to occur.

For clear viewing of equations in Microsoft(R) Office Word documents, Euclid fonts are required. You can download them from http://www.dessci.com/en/dl/fonts/getfont.asp if you do not already have them.

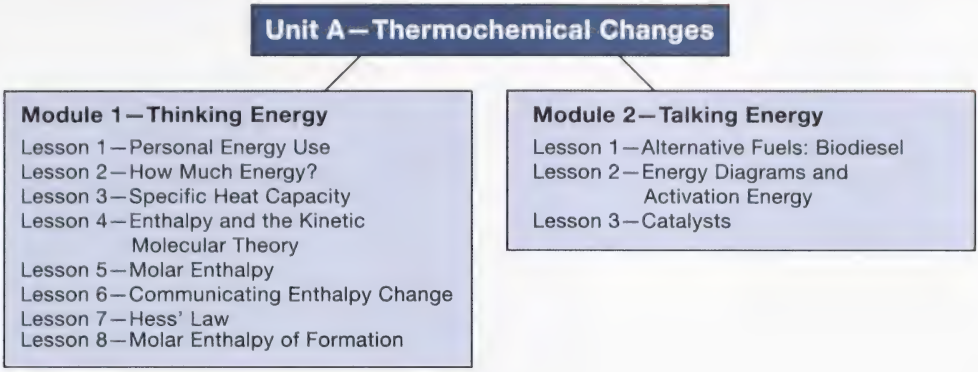
At the end of Unit A you will be able to

- determine and interpret energy changes in chemical reactions
- explain and communicate energy changes in chemical reactions

You will showcase what you have learned in the Unit A Assessment.

Concept Organizer

Unit A—Thermochemical Changes



Module Descriptions

Module 1—Thinking Energy

Module 1 examines how energy changes in chemical reactions are determined and interpreted. You will use calorimetry to measure enthalpy changes, and you will use standard molar enthalpies of formation to predict the magnitude of energy changes associated with chemical reactions.

You will consider the following module questions:

- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?
- How does society use knowledge of the energy associated with chemical processes to promote sustainability?
- In what ways have issues of energy use affected the development of past and present societies?

Module 2—Talking Energy

Module 2 investigates the events and energy changes associated with chemical reactions from the molecular level. You will learn about activation energy and the role that catalysts play in chemical processes. You will understand the function of catalysts from the perspective of chemical energetics.

You will consider the following module question:

- What energy changes must be considered when designing chemical systems?

Using the Concept Organizer

Each module and lesson contains focusing questions intended to guide your study. Concept organizers are provided for each module. The Module 1 and Module 2 concept organizers, which list the module and lesson questions, are provided at the end of this section.

As you work your way through each module, think about how the lesson questions relate to the module questions and to questions from other lessons. Use the concept organizers to build a concept map or a graphic organizer for each module. To do this, you might use software you already have on your computer, or you might do an Internet search for free software you can use. In your concept map or graphic organizer, record and demonstrate how the lesson and module concepts are connected and interdependent.

Sample concept maps are provided in the Module Summary for each module. Remember that the samples are just that—they show only one of many possible descriptions. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or compare your map or organizer to those of your classmates. This will ensure that your interpretations of lesson materials and your descriptions are accurate.

Module 1 Concept Organizer

L8 How are standard molar enthalpies of formation used to determine the enthalpy change associated with chemical reactions?

L1 How does society use the energy of chemical changes?

L7 How does Hess' law relate to enthalpies of reaction?

Module 1 Questions

Should energy be given a higher priority when making decisions about society's future?

L1 How do you use the energy of chemical changes in your life?

L7 What is Hess' law?

How does society use the energy of chemical changes?

L2 How is energy quantified?

What are the impacts of energy use on the environment?

L6 How are enthalpy changes communicated?

L3 How can knowledge of specific heat capacity be used in the design of a sleeping bag?

How does society use knowledge of the energy associated with chemical processes to promote sustainability?

L5 How can the energy richness of different fuels be compared?

L4 What changes occur during a chemical reaction at the particle level?

In what ways have issues of energy use affected the development of past and present societies?

L4 What is enthalpy?

L4 Why do chemical changes and energy changes occur at the same time?

Module 2 Concept Organizer

L1 What makes a good fuel?

L3 What is a catalyst?

Module 2 Questions

What energy changes must be considered when designing chemical systems?

L2 Why is energy needed to start an exothermic reaction?

L3 How does a catalyst influence a chemical reaction?

Module 1—Thinking Energy

Module Introduction

Energy is defined as the capacity of a substance or system to do work. Energy—including the development and export of natural resources such as coal, natural gas, oil, and bitumen from oil sand—is an important part of Alberta's economy. Energy is also an important part of your daily life. You rely heavily on fossil fuels to provide energy to heat your home and to power the machinery, equipment, electronics, and more that are part of almost every part of your life.

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Energy can come in a variety of forms. Almost all of the events that occurred earlier in your day today involved energy in some form. Your alarm clock's conversion of electrical energy into sound energy may have woken you up. Your water heater's transformation of chemical potential energy from natural gas or another fuel into thermal energy probably provided the warm water for your shower. In this module you will investigate the quantity of energy involved in your daily activities.

Module 1 will focus on various energy sources and will consider those sources within the context of providing energy for the activities you enjoy. You will learn ways to measure and calculate energy change during chemical reactions.

In Module 1 you will investigate the following questions:

- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?
- How does society use knowledge of the energy associated with chemical processes to promote sustainability?
- In what ways have issues of energy use affected the development of past and present societies?

Remember that each lesson will also be organized around questions intended to guide your study. As you proceed through Module 1, you may record answers to these questions and any interrelationships that exist between them in a concept map or graphic organizer.

More information is available in the Unit A Concept Organizer. In the Module 1 Summary you will receive further information on how you can use your concept map or graphic organizer to review the concepts you studied in this module.

Big Picture

Want to see the North? Canada's northern-most regions are becoming tourism hotspots. Before visiting the Arctic you will want to make sure your visit will not harm the area's delicate ecology. You might consider "going eco" on your next holiday!

© Jan Martin Will /shutterstock

Ecotourism—the opportunity to visit and observe natural habitat and wildlife without leaving a negative ecological footprint—is the new rage. Ecotourism encourages the use of sustainable resources and the promotion of sustainable development within the area visited. It also focuses on minimizing the impact of visitors on the wilderness showcased.

Ecotourism can provide for many unique holidays ranging from observing wildlife such as wolves, beluga whales, muskoxen, and caribou; to more energetic pursuits like canoe trips, whale watching in kayaks, travel by komatik, cross-country skiing, snow shoeing, and hiking. Ecotour accommodations vary from tents on the tundra to cozy lodges with gourmet meals.

When planning and delivering ecotours, ecoguides and tour operators must make many logistical decisions including how their tour participants will move around and what fuel will power any vehicles participants use.

In Module 1 you will plan an ecotour of the area in which you live. You will consider how thermodynamics can be applied to the type of equipment you will use and the practices you will follow during your ecotour. In your role as an ecotour operator you will evaluate what priority should be given to energy consumption when making decisions about your ecotour company and society's future.

As you develop a plan for your ecotour, you will consider the unique ecological, geological, or geographic aspects of your part of Alberta. Depending on where you live, you may develop a tour that features the stunning Cypress Hills or Rocky Mountains, the many lakes in the Lac La Biche area, or the many ways to navigate Edmonton's river valley.

Your ecotour planning will tie into the Module 1 Assessment. Read on to learn more about the lessons, activities, and assessments you will complete as you progress through Module 1.

Assessment in This Module

Each lesson contains a range of activities and assessment options. These include assignments, labs, and Self-Check, Try This, Discuss, Reflect and Connect, and Reflect on the Big Picture activities. Instructions will be provided for each of these activities so that you can appropriately focus your time and effort. Your teacher will tell you which assessment options to complete and which responses to submit for marks or feedback. Remember to save all of your work in your Chemistry 30 folder.

The following are examples of the activities you will complete:

- Choice of Snack Foods (Lesson 2)
- Choice of Sleeping Bag (Lesson 3)
- Recharging Hot Packs (Lesson 4)
- Evaluating Different Fuels (Lesson 5)
- Evaluating Two Liquid Fuels (Lesson 6)
- Reflect on the Big Picture (Lesson 8)

For your Module 1 Assessment, you will submit your responses to your choice of four of the above activities as part of the planning component of your ecotour. You will also develop an advertising brochure to describe and attract tourists to the tour you are providing.

More information about the components of your ecotour plan is provided in the lessons and in the Module Assessment. You may wish to look at the Module Assessment and the Unit Assessment before starting Lesson 1.

In This Module

Lesson 1—Personal Energy Use

In Lesson 1 you will consider how your body and other biological systems use energy. You will learn about the origin of the energy in the food you eat. You will review the processes of photosynthesis, cellular respiration, and the carbon cycle; and you will consider their importance to the energy sources used by society.

You will investigate the following lesson questions:

- How does society use the energy of chemical changes?
- How do you use the energy of chemical changes in your life?

Lesson 2—How Much Energy?

How is the energy content of a food determined? In Lesson 2 you will use calorimetry to quantify energy associated with a chemical process or a food. You will use knowledge gained in this lesson to select foods to meet the energy requirements of clients in your ecotourism company.

You will investigate the following lesson question:

- How is energy quantified?

Lesson 3—Specific Heat Capacity

In Lesson 3 you will look at an important thermodynamic property unique to each substance-specific heat capacity. You will use your knowledge of specific heat capacity to evaluate materials with respect to their insulating properties.

You will investigate the following lesson question:

- How can knowledge of specific heat capacity be used in the design of a sleeping bag?

Lesson 4—Enthalpy and the Kinetic Molecular Theory

In Lesson 4 you will consider the changes in energy that are associated with chemical change.

You will investigate the following lesson questions:

- What changes occur during a chemical reaction at the particle level?
- Why do chemical changes and energy changes occur at the same time?
- What is enthalpy?

Lesson 5—Molar Enthalpy

In Lesson 5 you will learn more about enthalpy. You will understand the importance of knowing the enthalpy change for a chemical reaction per mole of reactants involved and how this may be used to evaluate different fuels used by your ecotourism company.

You will investigate the following lesson question:

- How can the energy richness of different fuels be compared?

Lesson 6—Communicating Enthalpy Change

In Lesson 6 you will learn different ways to communicate enthalpy changes for a chemical reaction.

You will investigate the following lesson question:

- How are enthalpy changes communicated?

Lesson 7—Hess' Law

In Lesson 7 you will learn to use Hess' law, an alternative method to calculate enthalpy change for a system without using a calorimeter. You will consider why this method might be used instead of obtaining a value through experimentation.

You will investigate the following lesson questions:

- What is Hess' law?
- How does Hess' law relate to enthalpies of reaction?

Lesson 8—Molar Enthalpy of Formation

In Lesson 8 you will use standard molar enthalpies of formation to calculate the enthalpy change for a chemical reaction.

You will investigate the following lesson question:

- How are standard molar enthalpies of formation used to determine the enthalpy change associated with chemical reactions?

Module 1—Thinking Energy

Lesson 1—Personal Energy Use

Get Focused

In this lesson you will investigate the energy changes that occur during the chemical reactions involved in photosynthesis, cellular respiration, and combustion. You will learn how these reactions are part of the carbon cycle.

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As you work through the lesson, you will be planning an ecotour. As an ecotour operator, you are responsible for your clients and for their impact on the environment in which your tour operates. Planning your ecotour will require you to consider how energy changes relate to situations outside of a chemistry laboratory.

You will need to keep your clients well-fed by offering them appropriate foods. While there are many qualities to consider when selecting food, in this case you will focus on the energy content of food. To get an idea of how much food your clients will need, you will do an inventory of and evaluate your own personal energy intake and needs.

Energy is involved in every activity. In this lesson you will investigate the quantity of energy you intake to support your daily activities.

Consider the following questions as you complete Lesson 1:

- How does society use the energy of chemical changes?
- How do you use the energy of chemical changes in your life?

Module 1: Lesson 1 Assignment

In the Lesson 1 Assignment you will prepare a spreadsheet to calculate your personal energy intake. You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 1 Assignment later in this lesson.

The other questions in this lesson are not marked by the teacher; however, you should still answer these questions. The Self-Check, Try This, and other types of questions are placed in this lesson to help you review important information and build key concepts that may be applied in future lessons. You should record the answers to all the questions in the lesson and place those answers in your course folder.

After a discussion with your teacher, you must decide what to do with the questions that are not part of your assignment. For example, you may decide to submit the responses to Try This and other questions that are not marked to your teacher for informal assessment and feedback. Your answers are very important to your teacher. They provide your teacher with information about your learning, and they help your teacher identify where adjustments to your instruction may be necessary.

Explore

Ultimate Energy Sources

Self-Check

Combustion processes are used by many cultures to obtain energy. Refer to the following pictures to answer the Self-Check questions below.

left: © Péter Gudella /shutterstock right: R. Knights/NWT Archives

SC 1. The photos above illustrate three combustion processes. Where does the energy within each fuel come from?

SC 2. Draw a diagram that traces the energy source in each of the fuels back to its origin. Save a copy of the diagrams in your course folder. You may wish to refer to these later.

SC 3. State two additional ultimate energy sources?

Check your work with the answer in the appendix.

Read

Read pages 480 and 481 in the textbook, *Nelson Chemistry Alberta 20–30*.

Compare your answers to SC 1 and SC 2 with what you read in the textbook. Did you correctly identify the original source of energy for the three fuels? Modify your answer if you need to, and then place an updated copy in your course folder.

Read

What purpose does food have? Although taste is important, food is all about energy. How much energy do you require to perform your daily activities? Why are you hungrier after a hike in the mountains than when you are sitting and watching television?

To perform your daily activities, your body uses **chemical potential energy** from the food you consume. In previous science courses you learned that energy is measured in joules. The energy in food can also be measured in another unit, calories.

chemical potential energy: the form of energy present within the chemical bonds of a substance

Read the "Personal Use of Chemical Energy" case study on page 482 of the textbook. In the case study, you will investigate how you obtain energy from your diet and how energy intake should be balanced with activity level and other energy requirements.

Self-Check

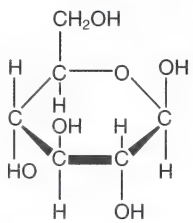
SC 4. Complete question 1 of the case study on page 482 in the textbook.

SC 5. Complete question 2 of the case study on page 482 in the textbook.

SC 6. Calculate the mass of glucose that would need to be consumed to meet the daily energy requirements of a normally active young adult. Use the values shown in the case study and the diagram of the glucose molecule.

SC 7. Repeat the calculations for a high-performance athlete.

Check your work with the answer in the appendix.



Glucose, $C_6H_{12}O_6(s)$

Read

Can you imagine having a diet in which you ate only glucose? A healthy diet contains other foods and energy sources.

Certain foods have more chemical potential energy than other foods. If you examine the diagram of the glucose molecule, you will identify a number of chemical bonds. The chemical potential energy you obtain from food is stored in the chemical bonds that hold molecules together. Your digestive system is designed to break these chemical bonds and to absorb or convert what you eat into carbohydrates, proteins, and fats that your body can access when it needs energy.

carbohydrate: a carbon compound that contains many hydroxyl groups and has the general chemical formula $C_nH_{2n}O_n$ (e.g., glucose, $C_6H_{12}O_6$)

Some types of chemical potential energy are easier for your body to use than others. Simple **carbohydrate** molecules, such as sugars like glucose, are a quick source of energy for the body because the molecule's bonds are easy to break. It takes the body longer to break the bonds in complex carbohydrates, like the starch found in pasta and whole-grain flour. Because they can provide a source of energy for a long period of time, complex carbohydrates are better for high-energy sports with long durations—hiking and cross-country skiing, for example.

Hikers and campers use information about different types of food to make informed choices when they pack for trips. They choose foods that pack a high-energy bang for the buck. Energy bars, which are a popular choice for many hikers, often include a mixture of simple and complex carbohydrate sources. These sources provide the immediate and long-term energy to support an activity.

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Going Beyond

The Canada Food Guide identifies types of foods and suggested quantities for consumption.

Food is more than just calories and kilojoules. The updated Canada Food Guide focuses on serving size and the number of servings eaten per day. In Modules 5 and 6 you will learn more about the carbohydrates, proteins, and fats contained in foods. You will also discover how these dietary components perform vital functions for your body.

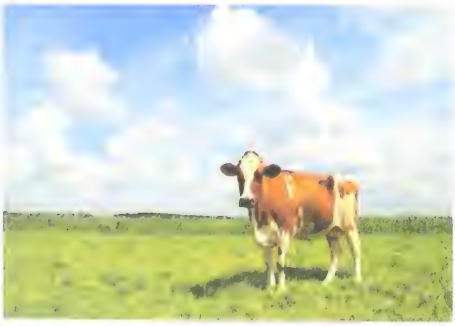
You may wish to use the Internet to obtain a copy of the Canada Food Guide or to find dietary information for athletes. This information will help you learn more about how appropriate nutritional and dietary choices can affect the health of your ecotour participants.

Module 1: Lesson 1 Assignment

How much energy do you consume each day by eating?

Go to the Module 1 Assignment Booklet, and complete "Module 1: Lesson 1 Assignment." In the assignment, you will record your personal energy intake in a spreadsheet.

The Sun—The Ultimate Energy Source



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Regardless of what food you eat, the energy you consume originally came from the sun. Solar energy is converted into chemical potential energy by plants as they photosynthesize. The energy contained within plants and/or animals is captured by living organisms when the plants and/or animals (the food) undergo a chemical reaction like digestion or combustion.

hydrocarbon molecule: a chemical compound containing only hydrogen and carbon atoms

Fossil fuels, such as coal, petroleum, natural gas, and oil sand, are an important energy source. Fossil fuels contain **hydrocarbon molecules**. Hydrocarbons typically tend to be high-energy molecules, since the chemical bonds between carbon atoms and between hydrogen and carbon atoms store a relatively large quantity of potential energy. Burning a fossil fuel releases the energy stored in these high-energy bonds. In your home, the combustion of fossil fuels can be used for many purposes, including heating your home.

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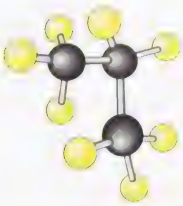
Coal is one type of fossil fuel composed of hydrocarbon molecules.



Propane, C_3H_8, is one of the hydrocarbons within natural gas.

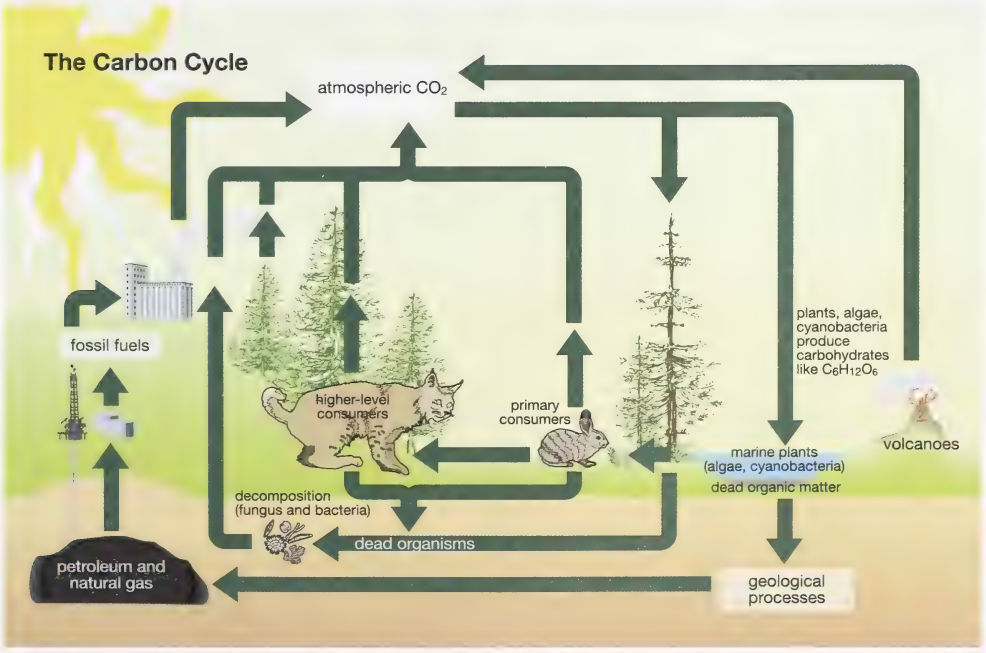
Try This

An Analysis of the Carbon Cycle

The carbon cycle is a summary of the major reactions involving carbon compounds in the biosphere. You may have seen a diagram of the carbon cycle in previous science courses. In this activity you will complete an analysis of a diagram of the carbon cycle.

Procedure

Step 1: Examine the diagram of the carbon cycle to refresh your memory of the carbon cycle and its processes.



Step 2: Prepare a chart listing similarities and differences between the following chemical processes, which are part of the carbon cycle: photosynthesis, cellular respiration, and combustion.

Include an example of a chemical reaction for each process in your chart. You may wish to use the Internet or other resources to find information.

Step 3: Examine the diagram of the carbon cycle. Determine the correct position on the diagram for each term you researched in Step 2.

TR 1. Write a brief paragraph to identify the important aspects of the carbon cycle.

TR 2. How is a knowledge of the carbon cycle important to your efforts to design an ecotour that will minimize impacts on the environment?

Post your answers to questions TR 1 and TR 2 in the discussion area for your class. Read the answers from at least two other students. If you wish, revise your answer. Place a copy of your revised answers in your course folder.

Reflect and Connect

top left: © cappi thompson /shutterstock top right: © Philip Lange /shutterstock
bottom: left: © Scott T. O'Donnell/shutterstock bottom right: © Alan Freed /shutterstock

All forms of transportation require energy. What forms of energy and energy sources are necessary in the forms of transportation shown in the graphic? What relationship do these forms of energy have to the sun? If you were planning an ecotour of your local area, which forms of transportation would best fit your tour's needs? Why would you have to rely on those forms of energy? Is there a way to make transportation in your area less harmful to the environment?

RC 1. Consider these questions and others you may have thought of as you worked through this lesson. Write answers or sketch notes to yourself. Create a sub-folder titled "ecotour planning" in your course folder. Save your answers and notes in this new sub-folder. You will refer back to this sub-folder throughout Module 1.

Reflect on the Big Picture

Ecotourism provides an opportunity to preserve natural areas by promoting sustainable travel. Ecotourists want to learn and experience the resources of an area but do not want to adversely affect the area's environment. In this lesson you began to consider some of the aspects of an ecotour. You will continue to consider other aspects of ecotourism in the coming lessons.

Use this opportunity to make some initial plans for your ecotour.

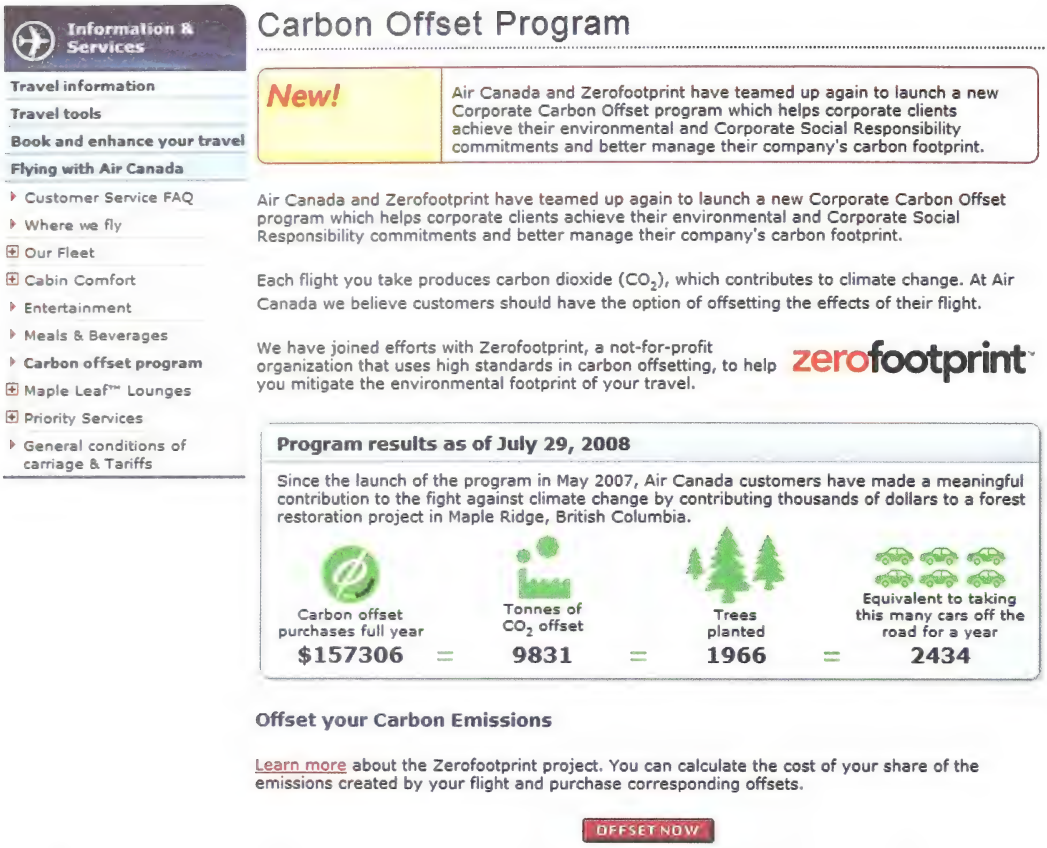
- What is unique about the area in which you live? How could this be the foundation for an ecotour?
- What locations will you visit in your ecotour?
- What activities will you do while you are at these locations?
- How will the participants in your ecotour get to and from these locations?
- How will your participants explore the different regions you take them to?
- Can you make the tour accessible to people with disabilities and, if so, what changes might you have to make to your plans?

Estimate the activity level of the participants in your ecotour. Use that information and the information you gathered about your own personal energy intake and requirements in your Lesson 1 Assignment to identify the foods you will need to meet your participants' energy needs.

Place your brief answers to these questions and any other ideas you have in your ecotour planning sub-folder.

Try This

Buying carbon offsets has become an option for many travellers.



Information & Services

- Travel information
- Travel tools
- Book and enhance your travel
- Flying with Air Canada
- Customer Service FAQ
- Where we fly
- Our Fleet
- Cabin Comfort
- Entertainment
- Meals & Beverages
- Carbon offset program
- Maple Leaf™ Lounges
- Priority Services
- General conditions of carriage & Tariffs

Carbon Offset Program

New! Air Canada and Zerofootprint have teamed up again to launch a new Corporate Carbon Offset program which helps corporate clients achieve their environmental and Corporate Social Responsibility commitments and better manage their company's carbon footprint.

Air Canada and Zerofootprint have teamed up again to launch a new Corporate Carbon Offset program which helps corporate clients achieve their environmental and Corporate Social Responsibility commitments and better manage their company's carbon footprint.

Each flight you take produces carbon dioxide (CO_2), which contributes to climate change. At Air Canada we believe customers should have the option of offsetting the effects of their flight.

We have joined efforts with Zerofootprint, a not-for-profit organization that uses high standards in carbon offsetting, to help you mitigate the environmental footprint of your travel.

zerofootprint™

Program results as of July 29, 2008

Since the launch of the program in May 2007, Air Canada customers have made a meaningful contribution to the fight against climate change by contributing thousands of dollars to a forest restoration project in Maple Ridge, British Columbia.

Carbon offset purchases full year		Tonnes of CO_2 offset		Trees planted		Equivalent to taking this many cars off the road for a year
$157306	=	9831	=	1966	=	2434

Offset your Carbon Emissions

Learn more about the Zerofootprint project. You can calculate the cost of your share of the emissions created by your flight and purchase corresponding offsets.

OFFSET NOW

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TR 3. What is a carbon offset?

TR 4. Is offering a traveller the opportunity to purchase a carbon offset consistent with the principles of ecotourism?

TR 5. Does allowing a traveller the opportunity to buy a carbon offset make this person more conscious of society's choices regarding energy use?

Place your answers to these questions in your ecotour planning sub-folder. You will be asked to review the information in this sub-folder as you finalize your ecotour plans later in Module 1. For example, you may use the information you gather on carbon offsets to determine whether your tour will include the option to purchase a carbon offset.

Lesson Summary

In Lesson 1 you considered the following questions:

- How does society use the energy of chemical changes?
- How do you use the energy of chemical changes in your life?

Society uses a variety of energy sources. Greater consideration has recently been given to the environmental impact of energy use. In this lesson you learned about a variety of energy sources. These included chemical potential energy in the food you eat, the fossil fuels used for many modes of transportation, and solar energy, which is the ultimate energy source for the biosphere. You learned about the chemical reactions involved in photosynthesis, cellular respiration, and combustion; and you learned how these reactions are part of the carbon cycle.

You also assessed your personal energy intake to get an idea of how much chemical potential energy your body needs to sustain itself. You used this information to start planning your ecotour.

Lesson Glossary

carbohydrate: a carbon compound that contains many hydroxyl groups and has the general chemical formula $C_nH_{2n}O_n$ (e.g., glucose, $C_6H_{12}O_6$)

chemical potential energy: the form of energy present within the chemical bonds of a substance

hydrocarbon molecule: a chemical compound containing only hydrogen and carbon atoms

Module 1—Thinking Energy

Lesson 2—How Much Energy?

Get Focused

In Lesson 1 you identified your daily energy intake from food. The food you eat provides you with chemical potential energy to maintain your body functions and your activity level. Although foods can vary greatly in the quantity of energy they provide, the energy contained within all food can be traced back to the sun—the biosphere's ultimate energy source.

The initial planning you completed for your ecotour in Lesson 1 probably indicates that your tour participants will be active. They will need to replace the energy they burn completing the many activities you have planned for them. You may recall calculating the energy required to complete some work in a previous science course, but how is the energy in food determined? How can chemical potential energy in food be measured?

In this lesson you will investigate how the energy content of food is determined and how the principles used to collect energy are applied to other technologies. You will use what you learn to create a list of foods to offer the participants in your ecotour.

Consider the following question as you complete Lesson 2:

- How is energy quantified?

Module 1: Lesson 2 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 2 Assignment later in this lesson. You will receive further instructions on how to complete this assignment later in this lesson.

In this lesson, you will also receive further instructions on, and you will complete, part of the Module 1 Assessment: Choice of Snack Foods.

You must decide what to do with the questions that are not marked by your teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You may decide to respond to all the questions and place those answers in your course folder.

Explore

Try This

Ranking Foods by Their Energy Content

Procedure

Step 1: Find at least ten foods in your home.

Step 2: Predict the amount of energy contained in one serving of each food by ranking the foods from highest to lowest energy content.

Step 3: Use the nutrition label or the Internet to determine the energy content of each food. If the energy content is given in calories, multiply the number of calories by 4.19 and record the value as kilojoules (kJ) in your table.

Analysis

TR 1. Calculate the energy content per gram for each food. Rank the foods from highest to lowest energy content per gram.

TR 2. Compare your ranking of predicted energy content with your ranking based on calculated values. Explain any differences.

Read

How is the energy content of food determined? Read pages 485–489 in the textbook to learn more about a **calorimeter** and **calorimetry**.

calorimeter: an isolated system in which the chemical system being studied is surrounded by a known quantity of liquid

calorimetry: the technological process of measuring the energy changes of an isolated system

Watch and Listen

To understand how thermochemistry is used to determine the quantity of energy available in food, go to the course multimedia DVD, and read "Food Energy." This is a transcript of an audio clip available on the website for the textbook. To listen to the audio clip, go to www.science.nelson.com and follow the links to Unit 6, Chapter 11, Section 11.2, Extension. You may need to ask your teacher for a username and password to access the audio clip.

In the audio clip and transcript, reference is made to a more sophisticated type of calorimeter, a bomb calorimeter. Go to the course multimedia DVD, and view "The Oxygen Bomb Calorimeter."

Lesson 2 Lab: Constructing and Testing a Calorimeter

A simple calorimeter can be used to determine the energy content of a nut, a type of food commonly found in trail mix.

Read the exploration "Burning Oil" on page 479 in the textbook.

Then, go to the course multimedia DVD, and view the virtual investigation "Lesson 2 Lab: Calorimetry."

Module 1: Lesson 2 Assignment

Go to the Assignment Booklet. Use the information from the multimedia presentation to complete "Part 1: Calorimetry Lab." You will receive information later in the lesson on when to complete the rest of the Lesson 2 Assignment.

Going Beyond

Calorimetric data about the energy content in foods is not always reliable. Use the Internet to research other methods used to determine the energy content in foods. Why are other methods used? Do the other methods have limitations or do they provide greater accuracy than calorimetric data?

Self-Check

SC 1. Complete "Practice" questions 1 to 8 on page 487 in the textbook.

Check your work with the answer in the appendix.

Evaluate the Design of a Solar Panel

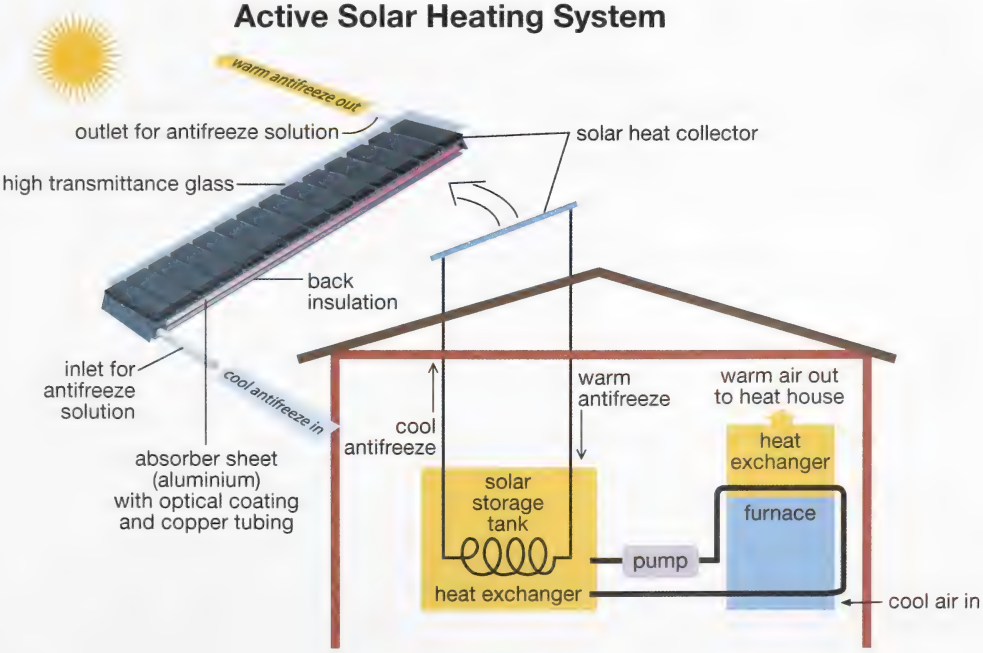
Watch and Listen

Drake Landing is an innovative neighborhood located in Okotoks, Alberta. Part of Drake Landing's innovation involves the way the development uses solar energy to greatly reduce the neighbourhood's dependence on fossil fuels. As shown in the picture, energy from the sun is used to heat homes. This greatly reduces the need for fossil fuels.

Natural Resources Canada

Go to the course multimedia DVD, and view the video "Drake Landing Solar Community" for more information on how a community solar heating system works.

The solar panels found on the roofs of buildings within the Drake Landing Solar Community are part of an active solar heating system. The circulation of antifreeze solution through the system allows for the transfer of energy from the collector to the house or to the borehole energy storage system.



This is a schematic representation of a solar heating system and its components.

Module 1: Lesson 2 Assignment

Go to the Assignment Booklet, and use your knowledge of energy transfers and of how an energy-measuring device such as a calorimeter works to complete "Part 2—Evaluate the Design of a Solar Collector."

Reflect on the Big Picture

As you work through Module 1, you are developing a plan for an ecotour. You have been saving related work to your ecotour planning sub-folder. Ecotourism is defined as "the responsible travel to natural areas that conserves the environment and improves the well-being of local people" (The International Ecotourism Society). At the start of Lesson 2 you investigated the energy content of different foods. What foods should the participants in your ecotour eat to maintain their energy and nutrition levels?

The International Ecotourism Society

Uniting Conservation, Communities and Sustainable Travel

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<www.iowr.ca>

Choice of Snack Foods

RBP 1. Prepare a list of snack foods that you intend to provide during the ecotour you are planning. Include the energy content of each food, and justify the food's use. Identify what you need to consider when selecting and using these products, and show how your use of these foods supports the principles of ecotourism. Place a copy of your list and supporting information in your ecotour planning sub-folder.

This is the first of six assignments that you can submit as part of your Module 1 Assessment. For more information, refer to the Module 1 Assessment.

Lesson Summary

In Lesson 2 you considered the following question:

- How is energy quantified?

You learned about calorimetry, which is an experimental technique used to measure energy transfers. You used the formula $Q = mc\Delta t$ to calculate the energy gain or loss by a system in order to determine the energy content of foods. You also investigated the design of calorimeters. And you applied your understanding of the principles of energy transfer to the operation of a solar collector.

Lesson Glossary

calorimeter: an isolated system in which the chemical system being studied is surrounded by a known quantity of liquid

calorimetry: the technological process of measuring the energy changes of an isolated system

Module 1—Thinking Energy

Lesson 3—Specific Heat Capacity

Get Focused

One of the essential pieces of gear for an ecotourist is a sleeping bag suited to the climate. A sleeping bag that is too warm will cause you to sweat, and one that makes you feel too cool will result in you shivering through the night. Sleeping bags are rated according to the materials used in their construction and can be suitable for temperatures ranging from −40°C to +15°C.

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A sleeping bag is designed to insulate a person by attempting to prevent an energy exchange between the person and the surroundings. In Lesson 2 you learned about the design of a calorimeter. It might sound like the insulating characteristics of a sleeping bag are similar to those of a calorimeter—both are designed to prevent an exchange of thermal energy between the "contents" and its surroundings.

In this lesson you will test a calorimeter that you construct using data collected while performing an experiment. You will also investigate the specific heat capacity of substances and relate this property to the selection of materials that may be used to design a sleeping bag.

Consider the following question as you complete Lesson 3:

- How can knowledge of specific heat capacity be used in the design of a sleeping bag?

Module 1: Lesson 3 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 3 Assignment later in this lesson. You will receive further instructions on how to complete this assignment later in the lesson. In this lesson, you will also receive further instructions on and you will complete part of the Module 1 Assessment: Choice of Sleeping Bag.

You must decide what to do with the questions that are not marked by your teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

Calorimetry is based on two scientific principles, the first and second laws of thermodynamics:

1. Energy can be neither created nor destroyed.
2. Heat naturally transfers from warmer to cooler objects.

Try This

TR 1. Look at "Figure 3" on page 486 in the textbook. Write an explanation of how the two laws of thermodynamics are shown in this diagram.

Post your explanation to the discussion area for your class. Read and post comments on the explanations made by two of your classmates. Place a copy of your original explanation and any comments you receive from your classmates in your course folder.

TR 2. Prepare a sketch of "Figure 3." Add labels and captions to your sketch that explain how the design of a sleeping bag employs thermodynamic principles to ensure that the user is comfortable while sleeping outdoors. Submit a copy of your diagram to your teacher for feedback.

Watch and Listen

Energy transfers are essential to the operation of a calorimeter. Go to the course multimedia DVD, and view the video "Energy Transfers" to view an experiment measuring energy transfers between a cold metal object and the water in a calorimeter. You will use the information from this video to answer Self-Check questions 1 and 2. You may wish to read the Self-Check questions before viewing the video.

Self-Check

Answer these Self-Check questions after viewing the video "Energy Transfers."

SC 1. Record observations that could be used to **quantitatively** demonstrate that an energy transfer has occurred.

quantitative: an observation that uses a numeric value

SC 2. What is the **magnitude** of this energy change?

Check your work with the answer in the appendix.

Read

magnitude: a value that indicates size or quantity

Specific heat capacity is the energy required to change the temperature of one gram of a substance one degree Celsius. As you watched the video "Energy Transfers" you observed that the water in the calorimeter decreased in temperature. Assume that the piece of metal placed into the calorimeter in the video was allowed to cool to –20.0°C in a freezer. Given this information and the data you collected from the video, could you determine the specific heat capacity of the metal object?

specific heat capacity: a physical property of matter

It is the energy required to raise the temperature of one gram of a substance one degree Celsius.

Self-Check

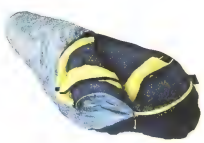
SC 3. Describe how you would use the data to determine the specific heat capacity of the metal object.

Check your work with the answer in the appendix.

SC 4. Use the data from the experiment to calculate the value for the metal's specific heat capacity.

Check your work with the answer in the appendix.

A sleeping bag is given a comfort rating, which is the lowest temperature limit at which the bag provides adequate insulation. Data from two sleeping bags are shown.



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Insulating Material	down	polyester
Comfort Rating	–7°C	–7°C
Weight	1.35 kg	1.37 kg

How do you think the two bags compare in terms of their specific heat capacities? Can you identify any assumptions involved in your prediction?

Although sleeping bags can appear to have similar heat capacities and insulating properties, their compositions can be very different. The style, the materials used in construction, and the method of assembly can influence the insulating properties and the comfort rating of sleeping bags.

Reflect and Connect

Thermal energy transfers between warmer and cooler objects until both objects reach the same temperature. The function of a sleeping bag, or the clothes you wear, is to contain the air around your body that has been warmed from heat your body has emitted. Materials that provide better insulation from the cold tend to prevent trapped air that has been heated by the body from escaping. It is common for winter campers to place a vapour bag within a sleeping bag. The vapour bag fits inside the sleeping bag like a sleeve and is designed to transfer perspiration (water) away from the air surrounding the body.

RC 1. The specific heat capacity of water is 4.19 kJ/(kg•°C), while the specific heat capacity of air is 1.01 kJ/(kg•°C). Use this data to explain how using a vapour bag can increase a person's comfort in a sleeping bag.

Post your answer to the discussion area for your class. Review the explanations provided by other classmates. Did all students have a similar understanding of how the difference in the value for specific heat capacity between water and air would affect the sleeping bag's insulating ability? Place a copy of your posting and your comments in your course folder.

Lesson 3 Lab: Constructing and Testing a Calorimeter

Background Information

In Lesson 2 you learned about bomb calorimeters and how they are used to measure the energy content of food. Bomb calorimeters are complicated technical devices and are not available in most high school science laboratories. In this investigation you will construct and determine the precision of a simpler version of a calorimeter.

Purpose

In this investigation you will construct and determine the precision of a calorimeter.

Problem

What is the precision of the calorimeter tested as determined by percent experimental error?

Open the Assignment Booklet. You will record data and complete your analysis in "Module 1: Lesson 3 Assignment."

Materials

- four polystyrene cups
- thermometer
- electronic balance
- water
- kettle

If you have access to the materials listed, you may be able to perform this investigation.

If you do not have access to these materials and a supervised laboratory, or if you would like to see the lab performed before you attempt it, go to the course multimedia DVD, and view the virtual investigation "Lesson 3 Lab: Constructing and Testing a Calorimeter." If you will not be completing the lab youself, remember to record data and observations as you view the presentation.

Procedure

Step 1: Construct a calorimeter by nesting two polystyrene cups.

Step 2: Make a hole in the bottom of the third polystyrene cup. A thermometer will be inserted into this hole later.

Step 3: Use the electronic balance to measure and record the mass of the calorimeter, including the lid.

Step 4: Remove the calorimeter from the balance. Add room temperature water to the calorimeter until it is just less than half full.

Step 5: Use the electronic balance to measure and record the mass of the half-full calorimeter, including the lid.

Step 6: Place the lid on the calorimeter and use the thermometer to measure the water temperature in the calorimeter.

Step 7: Use the kettle to prepare warm water with a temperature of approximately 60°C.

Step 8: Add warm water from the kettle to the fourth cup until it is just less than one-third full.

Step 9: Use the electronic balance to measure and record the mass of the fourth cup containing the warm water.

Step 10: Place the lid on the calorimeter and use the thermometer to measure the temperature of the warm water.

Step 11: Transfer the contents of the fourth cup to the calorimeter. Attach the lid to the calorimeter. Insert the thermometer through the hole made in Step 2, and use the thermometer to gently mix the contents of the calorimeter. While mixing the contents, observe the temperature change and record the highest temperature for the calorimeter contents.

Step 12: Use the electronic balance to measure and record the mass of the fourth cup.

Step 13: Empty the contents of the calorimeter, dry the inside of the calorimeter, and repeat Steps 4–12 to obtain data for nine more trials.

Step 14: Clean each apparatus used, and return each apparatus to its appropriate place in the laboratory.

Module 1: Lesson 3 Assignment

If you have not already done so, open the Assignment Booklet. Complete the "Module 1: Lesson 3 Assignment."

Self-Check

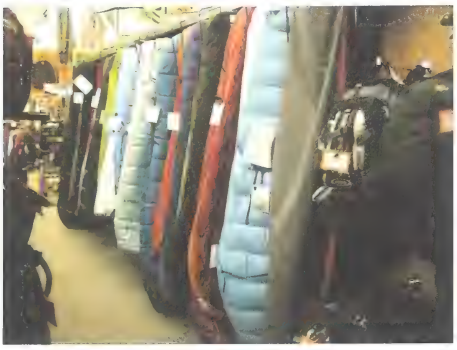
SC 5. Calculate the energy required to increase the temperature of a 175-g piece of copper from –25.0°C to 25.0°C.

SC 6. 6.0×10^3 J of energy is added to 150 g of water at 25.2°C. Calculate the final temperature of the water.

SC 7. Calculate the energy released by 1.50 kg of hot water at 100.0°C as it cools to room temperature (assume 24.5°C).

Check your work with the answer in the appendix.

Reflect and Connect



In this lesson you have investigated specific heat capacity and considered the effect that a difference in the specific heat capacity of water and/or of air may have on the ability of a sleeping bag to function in cold temperatures. The insulating properties of materials, whether used in a sleeping bag or for other purposes, are influenced by specific heat capacity and **thermal conductance**.

thermal conductance: the rate at which thermal energy flows through a substance

For example, the polystyrene used to make the cups of the calorimeter you used is a significantly better insulator than the glass used to make a beaker. Although polystyrene has a higher specific heat capacity than glass, polystyrene has a significantly lower thermal conductance, making it a better insulating material.

Choice of Sleeping Bag

Even if you don't plan to have your ecotour participants camp outdoors, a sleeping bag can be helpful if there are unexpected weather changes or if someone is injured. What type of sleeping bag will you provide for your clients?

Use the Internet and other sources to collect information about different types of sleeping bags. You may wish to collect information about comfort rating, design, insulating material, weight, durability, ease of cleaning, cost, and other relevant factors.

RC 2. Using the information you collect, prepare a chart comparing a minimum of two sleeping bag models. Choose which model will best meet your clients' needs and justify your choice. Add your results to your ecotour planning sub-folder.

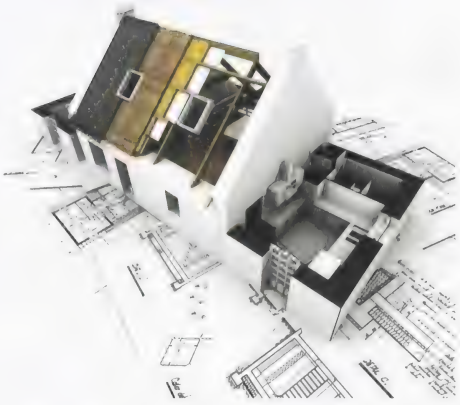
This is the second of six assignments that you can submit as part of your Module 1 Assessment. For more information, refer to the Module 1 Assessment.

Reflect on the Big Picture

Can you think of other ecotour aspects in which specific heat capacity might be important? Write these down, and place a copy of your answers in your course folder. You may wish to refer back to this list later in Module 1.

Going Beyond

Many new homes are being constructed in Alberta, and a large number of these buildings have highly energy-efficient designs. Use the Internet to find out more about the term *R-2000*. Find standards for new home construction, and compare these standards to construction practices of ten or more years ago. For example, you may wish to compare the design and materials used in your own home to those that meet R-2000 standards. How important is insulation and the specific heat capacity of materials to R-2000 design?



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Lesson Summary

In Lesson 3 you considered the following question:

- How can knowledge of specific heat capacity be used in the design of a sleeping bag?

You learned about specific heat capacity. Many devices use knowledge of the laws of thermodynamics and specific heat capacity in their designs. You also completed an investigation in which you used experimental data to calculate the specific heat capacity for water and to evaluate a calorimeter.

In future lessons you will continue to apply your knowledge about calorimetry and energy transfers to investigate energy changes in chemical systems.

Lesson Glossary

magnitude: a value that indicates size or quantity

quantitative: an observation that uses a numeric value

specific heat capacity: a physical property of matter

It is the energy required to raise the temperature of one gram of a substance one degree Celsius.

thermal conductance: the rate at which thermal energy flows through a substance

Module 1—Thinking Energy

Lesson 4—Enthalpy Changes

Get Focused

Cross-country skiing is a popular sport and may be one of the activities participants in your ecotour will undertake. Skiing is physically strenuous and requires a lot of energy. In addition to the large amount of energy used to cross the snow-covered terrain, a skier will expend energy to maintain his or her body temperature in cold winter weather. To conserve energy, paralympians sometimes use hot packs on their legs while training and racing on extremely cold days. Can you think of a similarity between a human body and a hot pack with respect to energy changes?

© Courtesy of Shauna Maria Whyte

In previous science courses you learned that the human body is designed to convert chemical energy from the food we eat into energy cells can use. Heat is a common by-product of cellular processes. A hot pack also releases energy as heat when a change occurs in the matter inside. Energy changes can be classified as either **exothermic** or **endothermic.** An exothermic process will warm its surroundings as it radiates energy. Endothermic processes absorb heat from the surroundings, often reducing the temperature of the surroundings.

exothermic: a process that radiates energy to its surroundings

endothermic: a process that absorbs energy from its surroundings

From your study of biology you know that humans are made up of millions of tiny cells. When you study chemistry you also consider the interactions of matter at the particle level. Why do the reactions involved in the use of food and those involved in the hot pack create heat? What is happening in both of these processes at the particle level, and how do those changes relate to the energy change involved in each of these processes? In Lesson 4 you will explore enthalpy changes.

Consider the following questions as you complete Lesson 4:

- What changes occur during a chemical reaction at the particle level?
- Why do chemical changes and energy changes occur at the same time?
- What is enthalpy?

Module 1: Lesson 4 Assignment

In this lesson you will

- draw cartoons to illustrate the different kinds of energy matter can have
- analyze calorimetric data and quantify the energy changes that occur
- review the assumptions involved in calorimetry as they relate to enthalpy changes

There is no assignment for this lesson; however, you will complete Try This, Reflect and Connect, and Reflect on the Big Picture activities, some of which may be useful for completing your Module 1 Assessment. You will also receive further instructions on, and you will complete part of the Module 1 Assessment: Recharging Hot Packs.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

Kinetic Molecular Theory

All matter is made of tiny particles. The **kinetic molecular theory** states that small particles that make up a substance are in continuous motion and collide with each other and with objects in their path. Motion associated with particles can involve more than collisions.

Read the bulleted lists under "Heat Transfer and Enthalpy Change" at the bottom of page 487 in the textbook to review the kinds of motion that are associated with a particle's **kinetic energy** and the associations between particles that involve **chemical potential energy**.

kinetic molecular theory: a theory that states that small particles that make up a substance are in continuous motion and collide with each other and with objects in their path

kinetic energy: a form of energy related to the motion of particles

Kinetic energy can involve vibration, rotation, or translation within or of a particle. Kinetic energy changes are often observed as a temperature change in matter.

chemical potential energy: a stored form of energy dependent on the relative positions of particles

Try This

Chemical Potential and Kinetic Energy

TR 1. By hand or digitally, prepare cartoons that depict the different kinds of energy matter can have. Save your work in your course folder and submit a copy to your teacher.

Read

The sum of the kinetic and potential energies in a system is called **enthalpy**. A system's enthalpy cannot be measured directly but can be determined indirectly by comparing the change in enthalpy of the products relative to the reactants.

enthalpy: the total kinetic and potential energy in a system

In Lesson 3 you used a calorimeter to measure energy changes that were the result of changes involving matter. How does the energy change for a process measured using a calorimeter relate to an enthalpy change?

Read page 488 in the textbook to learn more.

Try This

Energy Measured in a Calorimeter

TR 2. Write a paragraph to respond to the question in the Read activity above: how does the energy change for a process measured using a calorimeter relate to an enthalpy change? Save your response in your course folder and submit a copy to your teacher.

TR 3. Can you recall any other assumptions that are made in the design of a calorimeter or in interpreting the data collected from the calorimeter? How do these assumptions make it possible to measure the enthalpy change of a process that occurs within a calorimeter? Make sure you save a copy of your answers to these questions in your course folder as they will help you complete the next activity.

Read

Read page 489 and work through "Sample problem 11.1" and "Communication example 2" in the textbook.

Reflect and Connect

Energy Change of a Hot Pack

In this lesson you learned about enthalpy change and how an enthalpy change might be quantified using calorimetry. Complete the following activity to test your understanding of what you have learned.

Go to the course multimedia DVD, and view the video "Operation of a Hot Pack."

The following data were collected from a calorimetry experiment investigating the energy released by the hot pack shown in the video. Use your observations from watching the video and the data provided to complete the Analysis section below.

Data

mass of water in calorimeter = 550 g
initial temperature of water = 22.3°C
highest temperature of water = 30.7°C

Analysis

RC 1. The contents of the hot pack are listed as sodium acetate, water, and a metal disk. State the change that occurs to the arrangement of the sodium acetate particles during the operation of the hot pack.

RC 2. Is the type of change identified in your answer to RC 1 an example of a change in kinetic energy or potential energy? Support your answer.

RC 3. Explain why the change identified in your answer to RC 2 represents an enthalpy change.

RC 4. Use the data provided to determine the enthalpy change of the hot pack.

RC 5. Is the enthalpy change of the hot pack an exothermic or endothermic process? Support your answer by making specific reference to the data provided.

Save a copy of your responses in your course folder and submit a copy to your teacher.

Reflect on the Big Picture

Recharging Hot Packs

The hot pack used in the previous activity is reusable. When the hot pack is placed in boiling water, the solid sodium acetate dissolves and forms a colourless solution within the bag. If your ecotour takes place in winter, hot packs may be an essential piece of equipment for your operation. That could mean a lot of hot packs.

RBP 1. How might a reusable hot pack containing sodium acetate help minimize the negative ecological impact of your ecotour operation? Consider aspects such as energy changes and the reactivity and toxicity of the substances associated with the hot pack in developing your answer. Place a copy of your response in your ecotour planning sub-folder.

This is the third of six assignments that you can submit as part of your Module 1 Assessment. For more information, refer to the Module 1 Assessment.

Lesson Summary

In Lesson 4 you considered the following questions:

- What changes occur during a chemical reaction at the particle level?
- Why do chemical changes and energy changes occur at the same time?
- What is enthalpy?

You studied both theoretical and empirical aspects of matter and energy changes. You used cartoons and other methods to explain changes in matter and you analyzed data to calculate energy changes. You learned that an enthalpy change is the change in the kinetic and potential energy of a system and that an enthalpy change can be quantified using a calorimeter.

Lesson Glossary

chemical potential energy: a stored form of energy dependent on the relative positions of particles

endothermic: a process that absorbs energy from its surroundings

enthalpy: the total kinetic and potential energy in a system

exothermic: a process that radiates energy to its surroundings

kinetic energy: a form of energy related to the motion of particles

Kinetic energy can involve vibration, rotation, or translation within or of a particle. Kinetic energy changes are often observed as a temperature change in matter.

kinetic molecular theory: a theory that states that small particles that make up a substance are in continuous motion and collide with each other and objects in their path

Module 1—Thinking Energy

Lesson 5—Molar Enthalpy

Get Focused

Historically, Inuit living in the Arctic depended primarily on seal oil prepared from blubber as a fuel source for light, cooking, and heating. While using seal oil may seem peculiar, it was an ingenious use of this resource because of the oil's high caloric content, availability, and ease of use.

Go to the course multimedia DVD, and look at the photograph "Seal Oil Lamp."

In most modern societies, factors beyond availability and ease of use must be considered when choosing fuels. Cost and transportation are important factors. However, perhaps the most important consideration is energy richness.

How would you define the energy richness of a fuel? Could you incorporate some of the concepts you learned about in earlier Module 1 lessons to define energy richness? How might you determine the energy richness of a fuel? In this lesson you will learn how to use enthalpy changes to assess fuels.

Consider the following question as you complete Lesson 5:

- How can the energy richness of different fuels be compared?

Module 1: Lesson 5 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 5 Assignment later in this lesson. You will receive further instructions on how to complete this assignment later in this lesson.

In this lesson, you will also receive further instructions on and you will complete part of the Module 1 Assessment: Evaluating Different Fuels.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

In Lesson 4 you learned about enthalpy change. An enthalpy change occurs in every chemical reaction due to the change in potential energy associated with the change in bonding of the atoms involved. The energy change associated with a chemical reaction is called the **enthalpy of reaction.**

enthalpy of reaction: the change in the energy of a chemical system as it proceeds from reactants to products

It may not surprise you that overall energy changes associated with a reaction depend on the quantity of matter involved. For example, to get more heat out of your campfire for your ecotour participants, you would put more wood, or fuel, on the fire. It might surprise you that enthalpy change is not the same for all combustion reactions. You may have encountered this when you noticed that some fuels appear to release more energy than others when they combust.

How do you compare the enthalpy of reaction for different reactions? Read page 490 and work through "Sample problem 11.2" and "Communication example 3" on page 491 in the textbook to find out.

Try This

Molar Enthalpy of Fuel Combustion

Later in this lesson you will be asked to compare fuels. You will be given information about the molar enthalpy of reaction for each of the fuels to be compared. What does this information mean? Can you guess how a molar enthalpy of reaction for each fuel was determined?

TR 1. State the purpose of determining a molar enthalpy of combustion for different fuels.

TR 2. Describe an experiment that could be used to determine the molar enthalpy of combustion for a fuel. You may wish to determine the values you would need to measure during your experiment and then draft a formula that uses all your measured values.

Read the bottom section of page 491 in the textbook for help completing your description. You may wish to share your response to questions TR 1 and TR 2 with your teacher.

Read

The enthalpy of reaction is the change in enthalpy of a chemical system. **Molar enthalpy** is a change in enthalpy of a chemical system *per mole*. Molar enthalpy is helpful when assessing different fuels—just as "apples to apples" are compared in everyday life, molar enthalpy allows comparing "moles to moles" in chemistry.

molar enthalpy: a change in enthalpy of a chemical system *per mole*

Work through "Communication example 4" on page 492 in the textbook.

Self-Check

SC 1. Complete "Practice" questions 9–13 on page 492 in the textbook.

Check your work with the answer in the appendix.

Lesson 5 Lab: Molar Enthalpy of Neutralization

Background Information

The molar enthalpy for many chemical reactions can be determined experimentally, provided you have appropriate equipment. Earlier you constructed a calorimeter using nested polystyrene cups. In this investigation you will use a calorimeter to determine the molar enthalpy change for a neutralization reaction between aqueous sodium hydroxide and sulfuric acid solutions.

Purpose

To determine the molar heat of a chemical change (reaction), and to compare the experimentally obtained value with a widely accepted value for the $\Delta_n H_m$ for sodium hydroxide.

Experimental Design

The heat of reaction will be measured by combining 30.0 mL of 1.0 mol/L $H_2SO_4(aq)$ with 50.0 mL of 1.0 mol/L NaOH(aq). The two reactants will be combined in a simple calorimeter made of two polystyrene cups nested together. Assume that the specific heat capacity of both of these substances is equal to that of water, and that each of these solutions has a density identical to water.

Open the Assignment Booklet. You will record data and complete your analysis in the "Module 1: Lesson 5 Assignment."

Materials

- three polystyrene cups
- two 50-mL graduated cylinders
- thermometer
- mol/L H_2SO_4(aq)
- mol/L NaOH(aq)

If you have access to the materials listed, you may be able to perform this investigation.

If you do not have access to these materials and a supervised laboratory, or if you would like to see the lab performed before you attempt it, go to the course multimedia DVD, and view the virtual investigation "Lesson 5 Lab: Molar Heat of Neutralization." If you will not be completing the lab youself, remember to record data and observations as you view the presentation.

Procedure

Step 1: Nest two polystyrene cups.

Step 2: Measure 30.0 mL of 1.0 mol/L H_2SO_4(aq) solution using a 50-mL graduated cylinder and pour it into the calorimeter.

Step 3: Using another 50-mL graduated cylinder, measure 50.0 mL of NaOH(aq) solution.

Step 4: Record the temperature of each solution to the nearest 0.1°C.

Step 5: Pour the NaOH solution into the calorimeter. Use the third cup as a lid. Insert the thermometer into a hole in the lid, and slowly stir the mixture with the thermometer.

Step 6: Record the highest temperature obtained to the nearest 0.1°C.

Step 7: Pour the reaction mixture down the sink. The reaction mixture contains dilute excess sulfuric acid and acqueous sodium sulfate, and it does not require specific treatment prior to disposal. Rinse the calorimeter and other glassware used. Put all equipment away.

Module 1: Lesson 5 Assignment

If you have not already done so, open the Assignment Booklet. Go to the "Module 1: Lesson 5 Assignment," and complete "Part 1—Lab: Molar Heat of Neutralization." You will complete the rest of the Lesson 5 Assignment in the next activity.

Module 1: Lesson 5 Assignment

Evaluating Different Fuels

How would what you know about molar enthalpy apply to choosing a fuel for your ecotour operation? Are there other aspects to consider in your choice of fuel?

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Open the Assignment Booklet. Go to "Module 1: Lesson 5 Assignment," and complete "Part 2—Evaluating Different Fuels."

Also place a copy of your answers in your ecotour planning sub-folder. This is the fourth of six assignments that you can submit as part of your Module 1 Assessment. For more information, refer to the Module 1 Assessment.

Read

Reviews and summaries are an important part of learning. Read the "Summary" section on page 493 of the textbook.

Try This

To review what you have learned in the first five lessons in Module 1, try one of the following learning strategies:

- Review the concept map or graphic organizer you have been adding to throughout Module 1. Remember to use linking statements to explain how you understand the concepts to be connected.
- Use the Module 1 Concept Organizer as a starting point for another style of summarizing information (e.g., a list of key words, a concept map, a flow chart, or an outline).
- Review the lesson glossaries by covering up the definitions and defining each term in your own words.
- Create test questions and answers on flash cards.
- Write a script and record an audio file, podcast, or video introducing and explaining the major points listed in the "Summary" section on page 493 of the textbook.

Save your work in your course folder.

Reflect on the Big Picture

Earlier in this lesson you were asked to prepare a list of similarities and differences between enthalpy change and molar enthalpy. You realized there are many subtle differences to keep in mind as you continue to work through Unit 1.

One way to demonstrate your understanding of a concept is to create an analogy. An analogy explains a concept by comparing it to a similar but more familiar concept. For example, to express how fast people drive on German highways, you might say "Driving on the Autobahn in Germany is like driving on a racetrack."

RBP 1. Develop an analogy to explain what a molar enthalpy value is or is not. Your analogy may need to be more than one sentence.

Share your analogy with your classmates using the discussion area for your class. Submit a copy of your analogy to your teacher and save a copy in your course folder.

Lesson Summary

In Lesson 5 you considered the following question:

- How can the energy richness of different fuels be compared?

Molar enthalpy of reaction is a value describing the energy change associated with a chemical process per mole of one of the reactants or products involved in the process. In this lesson you calculated a molar enthalpy for a neutralization reaction, and you used molar enthalpy values to compare different fuels per mole of fuel.

As society is becoming more aware of humanity's impact on the environment, people are attempting to "go green." Your tour participants will expect your ecotour to use energy-rich alternative fuels.

Lesson Glossary

enthalpy of reaction: the change in the energy of a chemical system as it proceeds from reactants to products

molar enthalpy: a change in enthalpy of a chemical system *per mole*

Module 1—Thinking Energy

Lesson 6—Communicating Enthalpy Change

Get Focused

Campfires are a common sight on ecotours. They are a means of cooking food, providing warmth, and inspiring stories. Fire involves a combustion reaction—one of the most common exothermic reactions.

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As a science student you have been taught to observe chemical reactions for evidence of change, including energy change. What kinds of energy changes are occurring during a combustion reaction? In some reactions you can feel an increase in temperature or see light emitted.

In previous lessons you learned to quantify the energy change, as heat, associated with a chemical reaction. In this lesson you will further expand your understanding of enthalpy change. You will investigate how each of the following methods allows a process' enthalpy change to be clearly identified and associated with a specific chemical reaction:

- molar enthalpy of reaction for a specific reactant
- enthalpy change for a balanced reaction equation
- inclusion of the energy as a term in a balanced reaction equation
- chemical potential energy diagrams

Consider the following question as you complete Lesson 6:

- How are enthalpy changes communicated?

Module 1: Lesson 6 Assignment

There is no assignment for this lesson. However, you will be asked to submit samples of your work to your teacher for feedback where instructed.

In Lesson 8 you will complete an assignment on material covered in Lessons 6, 7, and 8. In preparation for the Lesson 8 Assignment, you may wish to summarize what you learn in Lessons 6, 7, and 8 as you proceed through these lessons. Your summary may take one of many forms (e.g., list, outline, concept map), depending on your individual learning style. Save a copy of your summary in your course folder so that you may quickly add to and review your summary in preparation for the Lesson 8 Assignment.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

In Lesson 5, you learned to calculate the enthalpy of a reaction per mole of one of the process' reactants or products. Communicating a reaction enthalpy in this way allows specific information to be expressed.

Enthalpy changes are communicated in four ways:

- molar enthalpy of reaction for a specific reactant
- enthalpy change for a balanced reaction equation
- inclusion of the energy as a term in a balanced reaction equation
- chemical potential energy diagrams

Read the text and work through the "Sample problems" and the "Communication examples" on pages 495–499 in the textbook. Complete TR 1 as you read.

Try This

TR 1. Complete a table like the following in your course folder to summarize the four methods as you read about them:

Question	Molar enthalpy of reaction for a specific reactant	Enthalpy change for a balanced reaction equation	Inclusion of the energy as a term in a balanced reaction equation	Chemical potential energy diagrams
How is this method done?				
What do I need to remember to do this method correctly?				

TR 2. Test your understanding and your summaries by attempting "Communication example 4" on page 500 in the textbook.

Post your table in the discussion area for your class and read the summaries of at least two other students. If necessary, revise your table. Save a copy of your revised table in your course folder.

Self-Check

SC 1. Complete "Section 11.3" questions 1, 2, 3, 4, 5, and 7 on page 501 of the textbook.

Check your work with the answer in the appendix.

Reflect on the Big Picture

Evaluating Two Liquid Fuels

Liquid fuels might be very useful in the operation of your ecotour. Two popular choices are methanol and ethanol.

RBP 1. Analyze the information below. Explain how your understanding of communicating enthalpy changes could help you identify which of these fuels is preferred with respect to its energy of combustion.

Fuel	Combustion Reaction Equation	$\Delta_c H^\circ$
Methanol	$2\ CH_3OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 4\ H_2O(g)$	–1275.8 kJ
Ethanol	$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$	–1234.8 kJ

Save a copy of your response in your ecotour planning sub-folder. This is the fifth of six assignments that you can submit as part of your Module 1 Assessment. For more information, refer to the Module 1 Assessment.

Module 1: Lesson 6 Assignment

There is no assignment for this lesson. Make sure you have saved a summary of what you've learned in Lesson 6 in your course folder. You will need this summary to complete the Lesson 8 Assignment.

Lesson Summary

In Lesson 6 you considered the following question:

- How are enthalpy changes communicated?

You learned that enthalpy changes can be communicated in the following four ways:

- molar enthalpy of reaction for a specific reactant
- enthalpy change for a balanced reaction equation
- inclusion of the energy as a term in a balanced reaction equation
- chemical potential energy diagrams

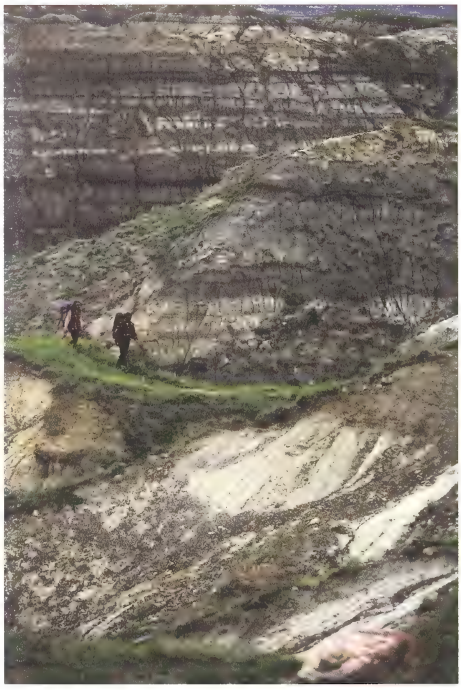
Each of these methods is useful for expressing the type and magnitude of enthalpy changes. You evaluated the importance of expressing enthalpy changes in each of these ways. You explained how communicating enthalpy changes could help you identify which fuels might be preferred for your ecotour.

Module 1—Thinking Energy

Lesson 7—Hess' Law

Get Focused

Hiking is a popular ecotour activity. Participants often want to see remote, untouched areas to get a sense of the natural habitat. Hiking in the Drumheller Badlands provides a great opportunity to learn about geology, paleontology, and other science disciplines while enjoying hiking's many other benefits.



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In the photograph shown, the trail the hikers are on dips downward and then slopes upward again. How do these small changes in elevation affect the hikers' level of effort?

In the last lesson you used chemical potential energy diagrams to represent the enthalpy change of a reaction. What does a change in position on a potential energy diagram represent?

You have probably hiked over hilly terrain before. Did you break your hike into manageable goals or steps? Did breaking your hike into steps affect the outcome of your day's effort? Chances are that thinking in steps and taking frequent breaks got you to the end of your journey refreshed and having enjoyed some of the sights along the way.

Breaking a hike into small steps could be an analogy for a chemical reaction performed as a series of steps that results in the desired products. Is there a difference in the enthalpy change of reaction for the total process when it occurs in steps?

Consider the following questions as you complete Lesson 7:

- What is Hess' law?
- How does Hess' law relate to enthalpies of reaction?

Module 1: Lesson 7 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 7 Assignment later in this lesson. You will receive further instructions later in this lesson on how to complete the assignment.

In Lesson 8 you will complete an assignment that covers material from Lessons 6, 7, and 8. It is important that you continue to summarize what you learn as you work through these lessons.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

In Lesson 2 you used a calorimeter to measure the enthalpy of a reaction. You also learned that by using a bomb calorimeter you can improve the reliability and range of reactions that you can investigate. However, is it possible to measure the enthalpy change of every reaction using a calorimeter? Is it possible to use your understanding of chemical potential energy to explain why energy changes occur during chemical reactions? Have you considered how this understanding might be used to determine the enthalpy change for a process if it cannot be done experimentally?

Read pages 502–503 in the textbook to learn about Hess' law.

Self-Check

SC 1. Identify two instances in which it is difficult to determine the energy change for a reaction experimentally using equipment normally found in a high school laboratory.

SC 2. Sketch "Figure 2" on page 503 of the textbook. Add details to your sketch to

- identify the separate reactions (steps) in the process
- explain why the overall enthalpy change is only –110.5 kJ, not –393.5 kJ

Check your work with the answer in the appendix.

Try This

Use your answers to the Self-Check questions and the information in your textbook to demonstrate your understanding of Hess' law by answering the following questions.

Consider the following information about a theoretical chemical system:

Reaction 1: $AB \rightarrow A + B \ \Delta_r H = +75$ kJ
Reaction 2: $A + CD \rightarrow AC + D \ \Delta_r H = -50$ kJ
Reaction 3: $BD \rightarrow B + D \ \Delta_r H = -125$ kJ
Net Reaction: $AB + CD \rightarrow AC + BD$

TR 1. Demonstrate how reactions 1–3 can be combined to yield the net reaction.

TR 2. Demonstrate how reactions 1–3 can be depicted on a potential energy diagram such that the enthalpy change for the net reaction is depicted.

TR 3. Demonstrate how the enthalpy change for reactions 1–3 are combined to result in an enthalpy change for the net reaction.

Submit your responses to your teacher and save a copy in your course folder. If your teacher provides feedback, carefully review his or her feedback and revise your answer, if necessary.

Post your responses to TR 1–3 in the discussion area for your class. Review the responses of at least two other students. Identify where your responses were similar to and different from your classmates' responses. If possible, evaluate the different approaches used by your classmates, and determine whether you might use parts of their strategies. If necessary, revise your answers to TR 1–3 and save a copy of your revised responses in your course folder.

Read

Work through "Sample problem 11.4" and "Communication example" on pages 503–504 in the textbook.

You may go to the website for your textbook to listen to the explanation of "Sample problem 11.4." Contact your teacher for instructions on how to access this website.

Review the "Summary" on page 504 of the textbook for clarification of the process used to solve these problems.

Self-Check

SC 3. Complete "Practice" questions 1–4 on pages 504–505 of the textbook.

Check your work with the answer in the appendix.

Try This

To some people, the most important rules for Hess' law are as follows:

1. If the chemical reaction is reversed, then the sign of the change in enthalpy is reversed.

2. If the coefficients of the chemical reaction are altered, then the change in enthalpy is also altered by the same factor.

It is easy to memorize these rules, but it is important to do more than memorize them—you must understand them.

TR 4. Write explanations that identify the scientific principles associated with each of these rules and state why these rules need to be considered when using Hess' law.

Save a copy of your response in your course folder.

Post a copy of your response to the discussion area for your class. Read the responses of at least two other students. Provide feedback to your classmates to help them ensure their explanations are clear and thorough. Revise your explanations based on the feedback you receive. Save a copy of your revised explanations in your course folder.

Module 1: Lesson 7 Lab—Applying Hess' Law

Purpose

To use Hess' law to determine the molar enthalpy of combustion for a reaction that cannot be determined experimentally with available equipment.

Problem

What is the molar enthalpy of combustion for magnesium?

Prediction

The accepted value for this reaction is –601.6 kJ/mol of magnesium reacted.

Open the Assignment Booklet. You will record data and complete your analysis in the "Module 1: Lesson 7 Assignment."

Materials

- lab apron
- eye protection
- magnesium ribbon
- magnesium oxide powder
- mol/L hydrochloric acid (100.0 mL for each trial)
- three polystyrene cups
- thermometer
- 100-mL graduated cylinder
- scoopula and weighing boat or paper
- steel wool
- electronic balance
- ruler

If you have access to the materials listed, you may be able to perform this investigation.

If you do not have access to these materials and a supervised laboratory, or if you would like to see the lab performed before you attempt it, go to the course multimedia DVD, and view the virtual investigation "Lesson 7 Lab: Applying Hess' Law." If you will not be completing the lab yourself, remember to record data and observations as you view the presentation.

Procedure

Part A

Step 1: Construct a calorimeter by nesting two polystyrene cups.

Step 2: Measure 100.0 mL of HCl(aq) and pour it into the calorimeter.

Step 3: Record the temperature of the contents of the calorimeter.

Step 4: Use the ruler to measure approximately 15 cm of magnesium ribbon.

Step 5: Use the steel wool to remove the coating from the magnesium ribbon.

Step 6: Measure and record the mass of the magnesium ribbon using the electronic balance.

Step 7: Add the magnesium ribbon to the calorimeter, and gently stir the calorimeter contents using the thermometer.

Step 8: Place the lid on the calorimeter, and record the highest temperature of the calorimeter contents.

Step 9: Empty the calorimeter into the appropriate waste container, and rinse the calorimeter with water.

Part B

Step 1: Measure 100.0 mL of HCl(aq) and pour it into the calorimeter.

Step 2: Record the temperature of the contents of the calorimeter.

Step 3: Measure and record approximately one gram of magnesium oxide.

Step 4: Add the magnesium oxide to the calorimeter, and gently stir the calorimeter contents using the thermometer.

Step 5: Place the lid on the calorimeter, and record the highest temperature of the calorimeter contents.

Step 6: Empty the calorimeter into the appropriate waste container and rinse the calorimeter with water.

Step 7: Return all materials to their place in the lab.

Module 1: Lesson 7 Assignment

If you have not already done so, open the Assignment Booklet. Complete the "Module 1: Lesson 7 Assignment."

Make sure you have saved a summary of what you've learned in Lesson 7 in your course folder. You will need this summary to complete the Lesson 8 Assignment.

Lesson Summary

In Lesson 7 you considered the following questions:

- What is Hess' law?
- How does Hess' law relate to enthalpies of reaction?

Hess' law is a thermodynamic principle that states that the addition of chemical equations yields a net chemical equation with an enthalpy change equal to the sum of the enthalpy changes of the steps. Hess' law can be used to determine the enthalpy change for reactions that are not able to be investigated experimentally. You evaluated the process used to investigate chemical reactions as multistep processes, and you completed a laboratory exercise to test a hypothesis made using Hess' law.

Module 1—Thinking Energy

Lesson 8—Molar Enthalpies of Formation

Get Focused

Since ecotours attract people from all over the world, you may wish to employ someone with a second language for your ecotour. Communication with your ecotour participants is very important, especially where activities involve important safety instructions.

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In previous lessons you learned many new terms, symbols, and methods for communicating aspects of thermodynamics. In Lesson 8 you will further your study of the enthalpy changes in chemical reactions by investigating the use of molar enthalpies of formation.

Consider the following question as you complete Lesson 8:

- How are standard molar enthalpies of formation used to determine the enthalpy change associated with chemical reactions?

Module 1: Lesson 8 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 8 Assignment later in this lesson. This assignment covers material learned in Lessons 6, 7, and 8.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

In previous lessons you may have noticed the difference between the symbols $\Delta_r H^\circ$ and $\Delta_r H$. The degree symbol means that a reaction enthalpy or other property of a system was measured at a standard state. A standard state is a defined set of conditions. You may recall learning two sets of standard conditions when working with gases: STP and SATP.

reference energy state: a reference point at which the potential energy of the elements in their most stable form at SATP is defined as zero

standard enthalpy of formation: the enthalpy change calculated from the measurements of a formation reaction under standard conditions

Read the first two paragraphs on page 510 in the textbook to learn more about the standard used in enthalpy determinations. Take note of the definitions for **reference energy state** and **standard enthalpy of formation**.

Self-Check

SC 1. Using an energy diagram, explain how defining elements as having a standard enthalpy of formation allows for the determination of standard enthalpies of formation for compounds.

Check your work with the answer in the appendix.

Read

Read the remainder of page 510 in the textbook to learn about the concept of **thermal stability**. Keep an image of an energy diagram fresh in your mind as you read.

thermal stability: the tendency of a compound to resist decomposition when heated

The lower a compound's standard enthalpy of formation, the more stable the compound.

Does the analogy stated in the textbook make sense to you? Which substance has greater thermal stability: octane ($\Delta_f H_m^\circ = -250.1$ kJ/mol) or trinitrotoluene (TNT, $\Delta_f H_m^\circ = +123.6$ kJ/mol)? Is your conclusion consistent with the reputations of these two compounds?

Read

Work through "Sample problem 11.5" on page 511 of the textbook to see how molar enthalpies of formation can be used to calculate enthalpies of reaction. You may also wish to read pages 512–513.

Self-Check

SC 2. Complete "Section 11.5" questions 2 and 3 on page 514 of the textbook.

Check your work with the answer in the appendix.

Self-Check

In the previous Self-Check activity you used the standard molar enthalpies of formation for compounds to predict the reaction enthalpy. Can this process be reversed?

If given a reaction enthalpy, most likely determined by experiment, a standard molar enthalpy of formation for a species in the reaction can be determined as long as the standard molar enthalpies of formation for the other species are known.

SC 3. Calculate the standard molar enthalpy of formation for hexane, $C_6H_{14}(l)$. Assume that hexane's standard molar enthalpy of combustion is −4162.9 kJ/mol.

Check your work with the answer in the appendix.

Reflect on the Big Picture

Standard molar enthalpies of formation allow for quick predictions of reaction enthalpies. Using the hiking analogy introduced in Lesson 7, these values provide an estimate of the chemical potential energy of each compound in the reaction equation. The difference between the potential energies of the products and the reactants is the reaction enthalpy. Using standard molar enthalpies of formation is a lot like knowing the checkpoints you must reach along your hike.

RBP 1. How would you use information on standard molar enthalpies of formation in your ecotour planning? Identify a situation in which this method of determining reaction enthalpy could be used. Identify where other methods and techniques learned in Module 1 could be applied to the operation of your ecotour.

Save a copy of your response in your ecotour planning sub-folder. This is the last of six assignments that you can submit as part of your Module 1 Assessment. For more information refer to the Module 1 Assessment.

Module 1: Lesson 8 Assignment

Open the Assignment Booklet, and complete the "Module 1: Lesson 8 Assignment."

Lesson Summary

In Lesson 8 you considered the following question:

- How are standard molar enthalpies of formation used to determine the enthalpy change associated with chemical reactions?

You learned about standards and reference points used to study energy changes. The reference point for standard molar enthalpies of formation states that the potential energy of elements in their most stable form at SATP is 0 kJ/mol. You also learned how to interpret values for standard molar enthalpies of formation to assess the thermal stability of compounds. You used these values much in the same way you used Hess' law, to calculate a reaction enthalpy.

Lesson Glossary

reference energy state: a reference point at which the potential energy of the elements in their most stable form at SATP is defined as zero

standard enthalpy of formation: the enthalpy change calculated from the measurements of a formation reaction under standard conditions

thermal stability: the tendency of a compound to resist decomposition when heated

The lower a compound's standard enthalpy of formation, the more stable the compound.

Module 1—Thinking Energy

Module Summary

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We live in a world that is dependent upon energy. In Module 1 you learned about energy and energy transformations.

You considered the following module questions:

- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?
- How does society use knowledge of the energy associated with chemical process to promote sustainability?
- In what ways have issues of energy use affected the development of past and present societies?

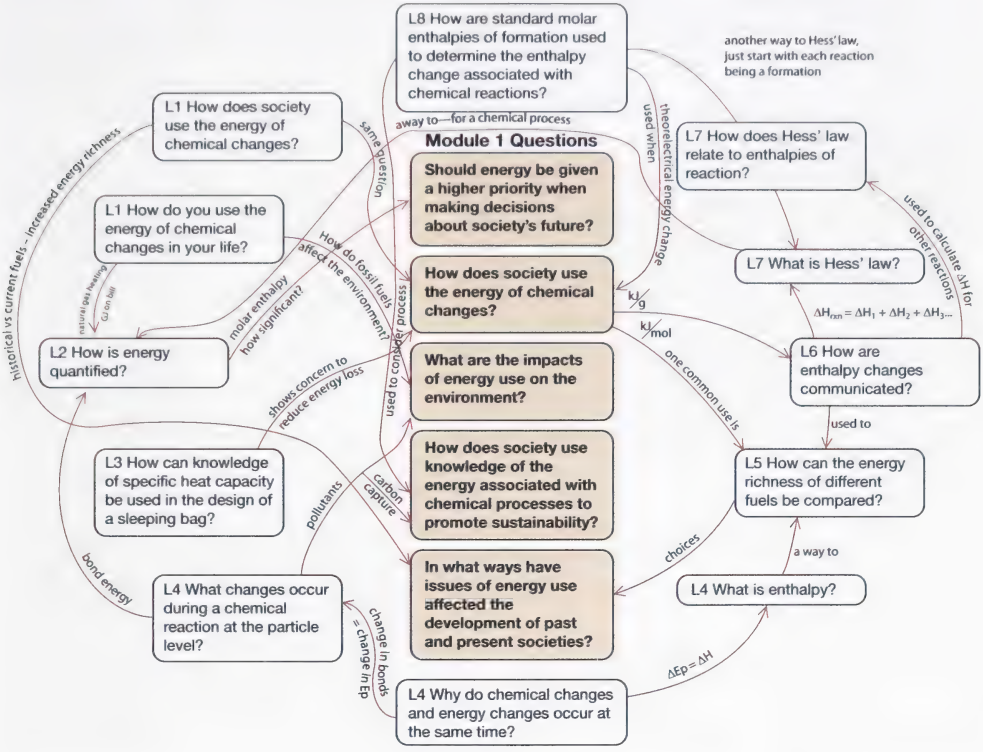
As you worked through Module 1, you developed an ecotour operating plan. You learned to identify and assess energy sources that society uses in a variety of ways, and you learned to evaluate various materials with respect to the specific heat capacity of each one. You also learned to evaluate fuels with respect to their energy change upon combustion and energy content per mole of fuel combusted.

In Module 2 you will further consider the differences between the energy content of different fuels. You will use this information to evaluate alternative fuels that could be used to fuel vehicles used in your ecotour.

Concept Map or Graphic Organizer

As you worked through Module 1, you may have added information to a concept map or graphic organizer based on the module and lesson questions listed in the Module 1 Concept Organizer. Now is a good time to review the relationships in your concept map or graphic organizer and to try to answer the module and lesson questions.

A sample Module 1 concept map is provided below and shows one set of possible links between the questions. Remember that this is one possible description only—there are many other correct possibilities. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or to compare your map or organizer with those of other students in your class. This will ensure that your interpretations of lesson materials and your descriptions are accurate.



Module Assessment

Ecotour Operations Plan

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1. In this module you began an operations plan for an ecotour. You considered what activities to offer to tourists and what food and equipment these activities would require. At the completion of this module your plan should include responses to the following activities:

    - Choice of Snack Foods (Lesson 2)
    - Choice of Sleeping Bag (Lesson 3)
    - Recharging Hot Packs (Lesson 4)
    - Evaluating Different Fuels (Lesson 5)
    - Evaluating Two Liquid Fuels (Lesson 6)
    - Reflect on the Big Picture (Lesson 8)

    Review your responses, and then select your best four responses for submission to your teacher.

2. Develop an advertising brochure to describe and attract tourists to the tour you are providing. Make sure your brochure explains how your tour is consistent with the principles of ecotourism.

    Submit your work to your teacher. Your Module 1 Assessment will also form part of your Unit A Assessment. Please see the Unit A Assessment for more information.

Scoring Guide for Ecotourism Company Brochure

Score	Criteria
5 Excellent	The response is a **thorough description and explanation** of an ecotour. The brochure is **attractive** and is written using **convincing** language and style. **Correct** choices and **explicit justifications** are made. **Detailed explanations** are used to identify how the proposed tour is consistent with the principles of ecotourism.
4 Good	The response is an **accurate description and explanation** of an ecotour. The brochure is **attractive** and is written using **convincing** language and style. **Correct** choices and **appropriate justifications** are made. **Detailed explanations** are used to identify how the proposed tour is consistent with the principles of ecotourism.
3 Satisfactory	The response is an **accurate description** of an ecotour. The brochure is **attractive** and is written using **appropriate** language and style. **Correct** choices and **supporting information** is identified. **Explanations** are used to identify how the proposed tour is consistent with some of the principles of ecotourism.
2 Limited	The response identifies **some aspects** of an ecotour. The brochure conveys a message with **limited impact** on the reader. **Some correct** choices are **supported**, but with **limited explanation and justification**.
1 Poor	The response identifies **an aspect** of an ecotour. The brochure **fails to convey** an appropriate message or tone to the reader. **Some relevant information** is provided but with **insufficient support and organization**.
0 Insufficient	The response is **incorrect and/or totally off topic**.

Module 1 Glossary

calorimeter: an isolated system in which the chemical system being studied is surrounded by a known quantity of liquid

calorimetry: the technological process of measuring the energy changes of an isolated system

carbohydrate: a carbon compound that contains many hydroxyl groups and has the general chemical formula $C_nH_{2n}O_n$ (e.g., glucose, $C_6H_{12}O_6$)

chemical potential energy: a stored form of energy dependent on the relative positions of particles

endothermic: a process that absorbs energy from its surroundings

enthalpy: the total kinetic and potential energy in a system

enthalpy of reaction: the change in the energy of a chemical system as it proceeds from reactants to products

exothermic: a process that radiates energy to its surroundings

hydrocarbon molecule: a chemical compound containing only hydrogen and carbon atoms

kinetic energy: a form of energy related to the motion of particles

Kinetic energy can involve vibration, rotation, or translation within or of a particle. Kinetic energy changes are often observed as a temperature change in matter.

kinetic molecular theory: a theory that states that small particles that make up a substance are in continuous motion and collide with each other and objects in their path

magnitude: a value that indicates size or quantity

molar enthalpy: a change in enthalpy of a chemical system *per mole*

quantitative: an observation that uses a numeric value

reference energy state: a reference point at which the potential energy of the elements in their most stable form at SATP is defined as zero

specific heat capacity: a physical property of matter

It is the energy required to raise the temperature of one gram of a substance one degree Celsius.

standard enthalpy of formation: the enthalpy change calculated from the measurements of a formation reaction under standard conditions

thermal conductance: the rate at which thermal energy flows through a substance

thermal stability: the tendency of a compound to resist decomposition when heated

The lower a compound's standard enthalpy of formation, the more stable the compound.

Appendix

Module 1 Self-Check Answers

Contact your teacher if your answers vary significantly from the answers provided here.

Lesson 1

SC 1. All energy sources originated from biological sources (wood, coal, and animal fat), meaning that the ultimate source of energy was the sun.

SC 2. Your diagrams should look like the following (arrows indicate the direction of the flow of energy):

sun → tree → firewood
sun → plant/animal tissue → coal
sun → plant life → fish → seal oil

Remember to place a copy of these diagrams in your course folder for a later look.

SC 3. The other ultimate energy sources include geothermal energy and gravitational energy.

SC 4. Food and fossil fuels are the two main sources of chemical energy for personal use.

SC 5.

$C_6H_{12}O_6(s)$

$$\begin{aligned} M_{\text{glucose}} &= (6\times 12.01\ \text{g/mol}) + (12\times 1.01\ \text{g/mol}) + (6\times 16.00\ \text{g/mol}) \\ &= 180.18\ \text{g/mol} \end{aligned}$$

$$\begin{aligned} n_{\text{glucose}} &= \frac{5.00\ \text{g}}{180.18\ \text{g/mol}} \\ &= 0.0278\ \text{mol} \end{aligned}$$

$$\begin{aligned} \text{energy released} &= 0.0278\ \text{mol}\times 2803.1\ \text{kJ/mol} \\ &= 77.8\ \text{kJ} \end{aligned}$$

SC 6.

$$\begin{aligned} \text{Daily intake}_{\text{normal young adult}} &= \frac{9\ \text{MJ}(1000\ \text{kJ/MJ})}{2803.1\ \text{kJ/mol}} \\ &= 3.21\ \text{mol} \end{aligned}$$

$$\text{Mass of glucose}_{\text{normal young adult}} = 3.21 \text{ mol} \times 180.18 \text{ g/mol}$$
$$= 579 \text{ g}$$

SC 7.

$$\text{Daily intake}_{\text{high-performance athlete}} = \frac{29 \text{ MJ}(1000 \text{ kJ/MJ})}{2803.1 \text{ kJ/mol}}$$
$$= 10.3 \text{ mol}$$

$$\text{Mass of glucose}_{\text{high-performance athlete}} = 10.3 \text{ mol} \times 180.18 \text{ g/mol}$$
$$= 1.86 \text{ kg}$$

Lesson 2

SC 1.

Practice 1.

Answers will vary but may be similar to either of the following responses:

- Energy cannot be created nor destroyed.
- All energy comes from some other form of energy.

Practice 2.

It is assumed that a calorimeter does not transfer energy with its surroundings. Therefore, a calorimeter is an isolated system.

Practice 3.

A calorimeter is used to measure the change in the system's thermal energy.

Practice 4.

a. If the mass of material undergoing temperature change is doubled and the other variables remain the same, then the thermal energy is doubled.

b. If the specific heat capacity of material undergoing temperature change is divided by two (is halved) and the other variables remain the same, then the thermal energy is halved.

c. If the temperature change of the material is tripled and the other variables remain the same, then the thermal energy is tripled.

d. If all three variables (m, c, and Δt) are doubled, then the thermal energy is increased by a factor of 8 ($2 \times 2 \times 2 = 8$).

Practice 5.

The values in "Table 1" on page 486 in the textbook show that iron has a lower specific heat capacity than aluminium. Therefore, iron requires less thermal energy to change temperature by one degree. As a result of its lower specific heat capacity, a 100-g iron mass would undergo a greater temperature change than a 100-g aluminium mass if the same quantity of energy were applied to both samples.

Practice 6.

$$\begin{aligned} Q &= mc\triangle t \\ &= 250\ \text{mL}(1\ \text{g/1 mL}) \times 4.19\ \text{J/(g•°C)} \times (95°\text{C} - 15°\text{C}) \\ &= 83\,800\ \text{J} \\ &= 84\ \text{kJ} \end{aligned}$$

The gain in the water's thermal energy is 84 kJ.

Practice 7.

$$\begin{aligned} Q &= mc\triangle t \\ &= 1.0\ \text{L}(1\ \text{kg/1 L}) \times 4.19\ \text{kJ/(kg•°C)} \times (97°\text{C} - 5.0°\text{C}) \\ &= 385.48\ \text{kJ} \\ &= 3.9 \times 10^2\ \text{kJ} \end{aligned}$$

The gain in the water's thermal energy is 3.9 x 10^2 kJ.

Practice 8.

$$\begin{aligned} Q &= mc\triangle t \\ &= 150\ \text{mL}(1\ \text{g/1 mL}) \times (1\ \text{kJ/1000 g}) \times 4.19\ \text{kJ/(kg•°C)} \times (52.8°\text{C} - 20.6°\text{C}) \\ &= 20.2377\ \text{kJ} \end{aligned}$$

$$\begin{aligned} \%\ \text{Efficiency} &= \left(\frac{20.2377\ \text{kJ}}{30.0\ \text{kJ}}\right)100 \\ &= 67.5\% \end{aligned}$$

The calorimeter is 67.5% efficient.

Lesson 3

SC 1.

Data Table

mass of empty cups	4.39 g
mass of cups and water	103.39 g
mass of water	99.0 g
final temperature of water	19.0°C
initial temperature of water	23.9°C

The decrease in the temperature of the water in the cup indicates that energy has been transferred from the water to the metal object placed in the water.

The magnitude of the energy change can be calculated using the formula $Q = mc\Delta t$, where

Q is the quantity of energy transferred by the water
m is the mass of the water in the system involved in the energy transfer
c is the specific heat capacity of water
Δt is the temperature change for the water in the system

SC 2.

$$\begin{aligned} Q &= mc\Delta t \\ &= 99.0\ \text{g} \times 4.19\ \text{J/(g}\bullet\text{°C)} \times (23.9\text{°C} - 19.0\text{°C}) \\ &= 2032.569\ \text{J} \\ &= 2.03 \times 10^3\ \text{J or } 2.03\ \text{kJ} \end{aligned}$$

The magnitude of the energy change for the water is 2.03 kJ.

SC 3.

Go to course multimedia DVD, and open "Specific Heat Capacity Worked Example—Part 1" to see the answer for this question.

SC 4.

Go to course multimedia DVD, and open "Specific Heat Capacity Worked Example—Part 2" to see the answer for this question.

SC 5.

$$Q = 175\ \text{g}\left(0.385\ \text{J/(g}\bullet^\circ\text{C)}\right)\left(25^\circ\text{C} - \left(-25^\circ\text{C}\right)\right)$$
$$= 3368.75\ \text{J}$$
$$= 3.4\ \text{kJ}$$

SC 6.

$$6.0 \times 10^3\ \text{J} = 150\ \text{g}\left(\frac{4.19\ \text{J}}{(\text{g}\bullet^\circ\text{C})}\right)\left(T_f - 25.2^\circ\text{C}\right)$$
$$T_f = 34.7^\circ\text{C}$$

SC 7.

$$Q = 1.50\ \text{kg}\left(\frac{4.19\ \text{kJ}}{(\text{kg}\bullet^\circ\text{C})}\right)\left(24.5^\circ\text{C} - 100.0^\circ\text{C}\right)$$
$$= -475\ \text{kJ}$$

475 kJ are released from the hot water as it cools.

Lesson 5

SC 1.

Practice 9.

a. $\Delta_f H$
b. $\Delta_d H$
c. $\Delta_f H_m$
d. $\Delta_d H_m$

Practice 10.

Similarities	Differences
Both contain the Δ and H symbols.	In molar enthalpy, the final character is a subscript lower-case m, indicating molar.
Both represent the energy change when a chemical change occurs.	The molar enthalpy of reaction is for a defined quantity of substance, one mole of a reactant or a product, involved in the reaction being studied.

Practice 11.

A positive value indicates that the process described is an endothermic process (energy is absorbed by the system when the reaction occurs). A negative value means that the process is exothermic (energy is released by the system when the reaction occurs).

Practice 12.

$$\begin{aligned}\Delta_c H &= -802.5 \text{ kJ/mol} \times \left(\frac{100 \text{ g}}{16.05 \text{ g/mol}} \right) \\ &= -5.00 \times 10^3 \text{ kJ}\end{aligned}$$

Practice 13.

$$\begin{aligned}\Delta_c H_m &= \left(650 \text{ g} \times 4.19 \text{ J/(g•°C)} \times 20.9°\text{C}\right) \div \frac{2.98 \text{ g}}{32.05 \text{ g/mol}} \\ &= -612 \text{ kJ/mol}\end{aligned}$$

Lesson 6

SC 1.

Section 11.3 1.

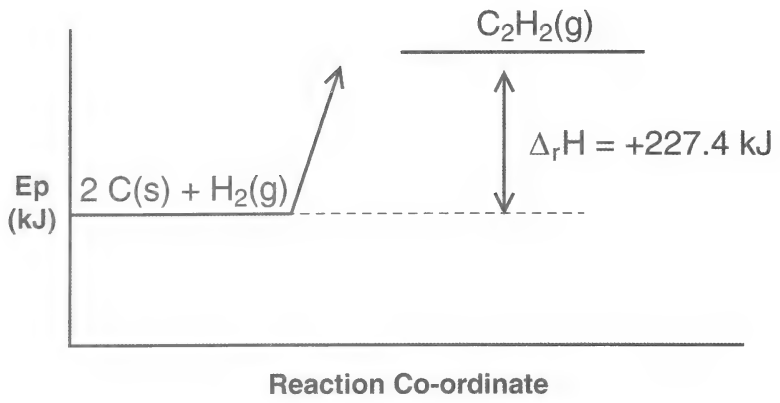
a. The symbols used represent the following: Δ = change, c = combustion, H = enthalpy, m = molar, ° = standard conditions. Therefore, the symbols represent the molar enthalpy change for a combustion reaction (e.g., methane at standard conditions).

b. The symbols used represent the following: n = amount, Δ = change, H = enthalpy, m = molar, ° = standard conditions. Therefore, the symbols represent the moles of one substance (e.g., propane) involved in a chemical process multiplied by its molar enthalpy of reaction (e.g., molar heat of combustion for propane).

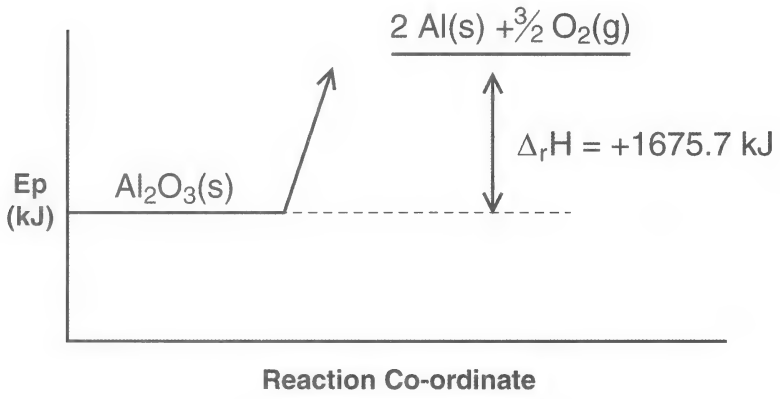
c. The symbol used represents the thermal energy change for water.

Section 11.3 2.

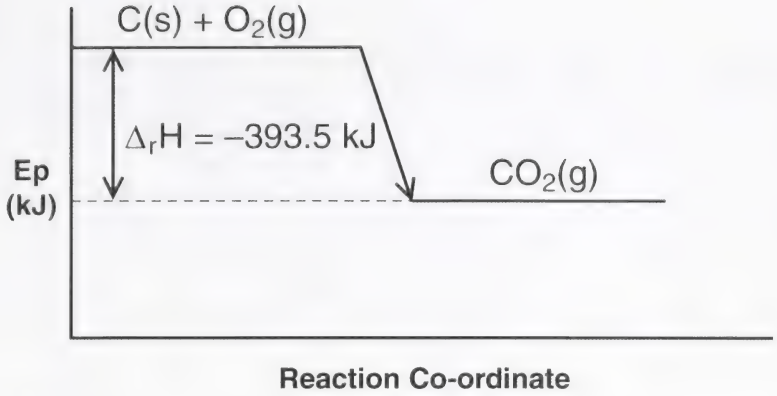
a. $\Delta_r H_m^\circ = +227.4$ kJ/mol
$2\,C(s) + H_2(g) \rightarrow C_2H_2(g)\ \Delta_r H^\circ = +227.4$ kJ
$2\,C(s) + H_2(g) + 227.4 \text{ kJ} \rightarrow C_2H_2(g)$



b. $\Delta_r H_m^\circ = +1675.7$ kJ/mol
$Al^2O_3(s) \rightarrow 2\ Al(s) + 3/2\ O_2(g)\ \Delta_r H^\circ = +1675.7$ kJ
$Al_2O_3(s) + 1675.7$ kJ $\rightarrow 2\ Al(s) + 3/2\ O_2(g)$



c. $\Delta_r H_m^\circ = -393.5$ kJ/mol
$C(s) + O_2(g) \rightarrow CO_2(g)\ \Delta_r H^\circ = -393.5$ kJ
$C(s) + O_2(g) \rightarrow CO_2(g) + 393.5$ kJ



Section 11.3 3.

a. $\Delta_r H_m^\circ = -241.8$ kJ/mol of hydrogen
b. $\Delta_r H_m^\circ = -318.0$ kJ/mol of ammonia
c. $\Delta_r H_m^\circ = +81.6$ kJ/mol of nitrogen
d. $\Delta_r H_m^\circ = -372.8$ kJ/mol of iron

Section 11.3 4.

a. $\Delta_r H = -114$ kJ
b. $H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)\ \Delta_r H = -114$ kJ
c. $\Delta_r H = -114$ kJ / 1 mol = –114 kJ/mol of sulfuric acid
d. $\Delta_r H = -114$ kJ / 2 mol = –57 kJ/mol of aqueous sodium hydroxide

Section 11.3 5.

a. $CH_3OH(l) + 3/2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g) + \Delta_c H = -725.9$ kJ
b. $C(s) + ¼\ S_8(s) \rightarrow CS2(l)\ \Delta_f H = +89.0$ kJ
c. $ZnS(s) + 3/2\ O_2(g) \rightarrow ZnO(s) + SO_2(g)\ \Delta_c H = -441.3$ kJ
d. $Fe_2O_3(s) \rightarrow 2\ Fe(s) + 3/2\ O_2(g)\ \Delta_{sd} H = +824.2$ kJ

Section 11.3 7.

a. $H_2(g) + ½\ O_2(g) \rightarrow H_2O(g)\ \Delta_r H = -285.8$ kJ
$H_2O(g) \rightarrow H_2(g) + ½\ O_2(g)\ \Delta_r H = +285.8$ kJ

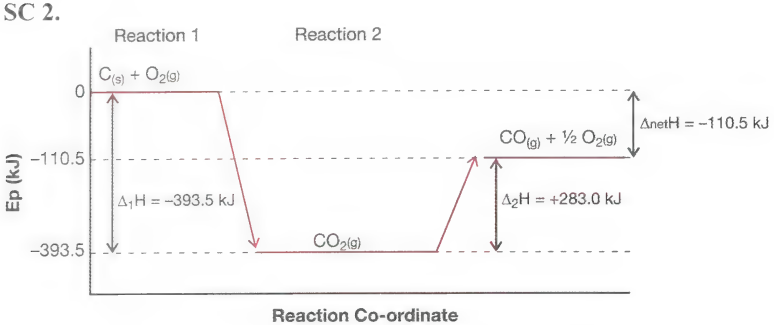
b. The magnitude of the enthalpy changes are identical, except that the combustion reaction is exothermic and the decomposition reaction is endothermic.

$\Delta_r H$(combustion) = $-\Delta_r H$(decomposition)

Lesson 7

SC 1. It may not be possible to determine the energy change for a reaction experimentally if the reaction occurs too slowly, if equipment is unavailable, or if there are safety concerns.

SC 2.



The overall change is –110.5 kJ, which represents the difference between the initial and final potential energies of the reactants and the final product. The sum of the reaction enthalpies is –110.5 kJ.

SC 3.

Practice 1.

$2\ Al(s) + \frac{3}{2}O_2(g) \rightarrow Al_2O_3(s)$ $\quad \Delta_1H = -1657.7$ kJ

$Fe_2O_3(s) \rightarrow 2\ Fe(s) + \frac{3}{2}O_2(g)$ $\quad \Delta_2H = +824.2$ kJ

$Fe_2O_3(s) + 2\ Al(s) \rightarrow Al_2O_3(s) + 2\ Fe(s)$ $\quad \Delta_rH = -833.5$ kJ

Practice 2.

$2\ C(g) + O_2(g)$	$\rightarrow$	$2\ CO(g)$	$\Delta_1H = -221.0$ kJ
$2\ H_2O(g)$	$\rightarrow$	$O_2(g) + 2\ H_2(g)$	$\Delta_2H = -221.0$ kJ
$2\ H_2O(g) + 2\ C(g)$	$\rightarrow$	$2\ CO(g) + 2\ H_2(g)$	$\Delta_rH = +262.6$ kJ
divide all by 2			
$H_2O(g) + C(g)$	$\rightarrow$	$CO(g) + H_2(g)$	$\Delta_rH = +131.3$ kJ

Practice 3.

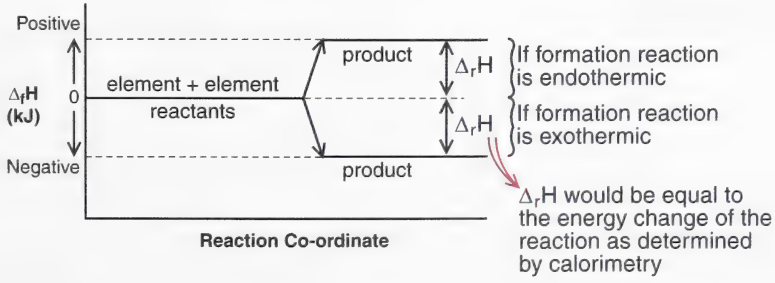
	$2\ CO(g)$		$2\ C(s) + O_2(g)$	$\Delta_1H = +221.0$ kJ
all multiplied by 2	$2\ C(s) + 2\ O_2(g)$	$\rightarrow$	$2\ CO_2(g)$	$\Delta_2H = -787.0$ kJ
	$2\ H_2(g) + O_2(g)$	$\rightarrow$	$2\ H_2O(g)$	$\Delta_3H = -483.6$ kJ
	$2\ CO(g) + 2\ H_2(g) + 2\ O_2(g)$	$\rightarrow$	$2\ CO_2(g) + 2\ H_2O(g)$	$\Delta_rH = -1049.6$ kJ
divide all by 2	$CO(g) + H_2(g) + O_2(g)$	$\rightarrow$	$CO_2(g) + H_2O(g)$	$\Delta_rH = -524.8$ kJ

Practice 4.

all multiplied by 3	$6\ H_2(g) + 3\ O_2(g)$	$\rightarrow$	$6\ H_2O(g)$	$\Delta_1H = -1450.8$ kJ
	$2\ CO(g)$	$\rightarrow$	$2\ C(s) + O_2(g)$	$\Delta_2H = +221.0$ kJ
all multiplied by 2	$2\ CO_2(g) + 4\ H_2O(g)$	$\rightarrow$	$2\ CH_4(g) + 4\ O_2(g)$	$\Delta_3H = +1605.4$ kJ
all multiplied by 2	$2\ C(s) + 2\ O_2(g)$	$\rightarrow$	$2\ CO_2(g)$	$\Delta_4H = -787.0$ kJ
	$6\ H_2(g) + 2\ CO(g)$	$\rightarrow$	$2\ CH_4(g) + 2\ H_2O(g)$	$\Delta_rH = -411.4$ kJ
divide all by 2	$3\ H_2(g) + CO_2(g)$	$\rightarrow$	$CH_4(g) + H_2O(g)$	$\Delta_rH = -205.7$ kJ

Lesson 8

SC 1.



SC 2.

Section 11.5 2.

a.

	Reactants		Products	
Species	$CH_4(g)$	$H_2O(g)$	$CO(g)$	$H_2(g)$
Coefficient (mol)	1	1	1	3
$\Delta_f H_m^\circ$ (kJ/mol)	−74.6	−241.8	−110.5	0
Σ n $\Delta_f H_m^\circ$	= [(1 mol × −74.6 kJ/mol) + (1 mol × −241.8 kJ/mol)] = −316.4 kJ		= [(1 mol × −110.5 kJ/mol) + (3 mol × 0 kJ/mol)] = −110.5 kJ	
$\Delta_r H^\circ$	= −110.5 kJ − (−316.4 kJ) = +205.9 kJ			

b.

	Reactants		Products	
Species	$CO(g)$	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
Coefficient (mol)	1	1	1	1
$\Delta_f H_m^\circ$ (kJ/mol)	−110.5	−241.8	−393.5 kJ	0
Σ n $\Delta_f H_m^\circ$	= [(1 mol × −110.5 kJ/mol) + (1 mol × −241.8 kJ/mol)] = −352.3 kJ		= [(1 mol × −393.5 kJ/mol) + (1 mol × 0 kJ/mol)] = −393.5 kJ	
$\Delta_r H^\circ$	= −393.5 kJ − (−352.3 kJ) = −41.2 kJ			

c.

	Reactants		Products	
Species	$N_2(g)$	$H_2(g)$	$NH_3(g)$	
Coefficient (mol)	1	3	2	
$\Delta_f H_m^\circ$ (kJ/mol)	0	0	−45.9	
Σ n $\Delta_f H_m^\circ$	= [(1 mol × 0 kJ/mol) + (3 mol × 0 kJ/mol)] = 0 kJ		= (2 mol × −45.9 kJ/mol) = −91.8 kJ	
$\Delta_r H^\circ$	= −91.8 kJ − (0 kJ) = −91.8 kJ			

Section 11.5 3.

a.

	Reactants		Products	
Species	$NH_3(g)$	$O_2(g)$	$NO(g)$	$H_2O(g)$
Coefficient (mol)	4	5	4	6
$\Delta_f H_m^\circ$ (kJ/mol)	−45.9	0	+91.3	−241.8
Σ n $\Delta_f H_m^\circ$	= [(4 mol × −45.9 kJ/mol) + (5 mol × 0 kJ/mol)] = −183.6 kJ		= [(4 mol × +91.3 kJ/mol) + (6 mol × −241.8 kJ/mol)] = −1085.6 kJ	
$\Delta_r H^\circ$	= −1085.6 kJ − (−183.6 kJ) = −902.0 kJ			

$$\triangle_r H_m^\circ = \frac{-902.0 \text{ kJ}}{4}$$
$$= -225.5 \text{ kJ/mol of ammonia}$$

b.

	Reactants		Products	
Species	NO(g)	O_2(g)	NO_2(g)	
Coefficient (mol)	2	1	2	
$\Delta_f H_m^\circ$ (kJ/mol)	+91.3	0	+33.2	
Σ n $\Delta_f H_m^\circ$	= [(2 mol × +91.3 kJ/mol) + (1 mol × 0 kJ/mol)] = +181.6 kJ		= (2 mol × +33.2 kJ/mol) = +66.4 kJ	
$\Delta_r H^\circ$	= +66.4 kJ − (+181.6 kJ) = −116.2 kJ			

$$\Delta_r H_m^\circ = \frac{-116.2 \text{ kJ}}{2}$$
$$= -58.1 \text{ kJ/mol of nitrogen monoxide}$$

c.

	Reactants		Products	
Species	NO_2(g)	H_2O(g)	HNO_3(l)	NO(g)
Coefficient (mol)	3	1	2	1
$\Delta_f H_m^\circ$ (kJ/mol)	+33.2	−285.8	−174.1	+91.3
Σ n $\Delta_f H_m^\circ$	= [(3 mol × +33.2kJ/mol) + (1 mol × −285.8 kJ/mol)] = −186.2 kJ		= [(2 mol × −174.1 kJ/mol) + (1 mol × +91.3 kJ/mol)] = −256.9 kJ	
$\Delta_r H^\circ$	= −256.9 kJ − (−186.2 kJ) = −70.7 kJ			

$$\Delta_r H_m^\circ = \frac{-70.7 \text{ kJ}}{3}$$
$$= -23.6 \text{ kJ/mol of nitrogen dioxide}$$

SC 3.

Balanced Reaction Equation

$C_6H_{14}(l) + 19/2\ O_2(g) \rightarrow 6\ CO_2(g) + 7\ H_2O(g)\ \Delta_r H_m^\circ = -4162.9\ kJ/mol\ C_6H_{14}(l)$

$\Delta_r H^\circ = -4162.9\ kJ/mol \times 1\ mol\ C_6H_{14}(l)$
$= -4162.9\ kJ$

	Reactants		Products		$\Delta r H^\circ$
Species	$C_6H_{14}(l)$	$O_2(g$	$CO_2(g)$	$H_2O(g)$	
Coefficient (mol)	1	19/2	6	7	
$\Delta_f H_m^\circ$ (kJ/mol)	?	0	−393.5	−241.8	
Σ n $\Delta_f H_m^\circ$	= [(1 mol × $\Delta_f H_m^\circ$(hexane)) + (19/2 mol × 0 kJ/mol)] = 1 mol × $\Delta_f H_m^\circ$(hexane)		= [(6 mol × −393.5 kJ/mol) + (7 mol × −241.8 kJ/mol)] = −4053.6 kJ		−4162.9 kJ

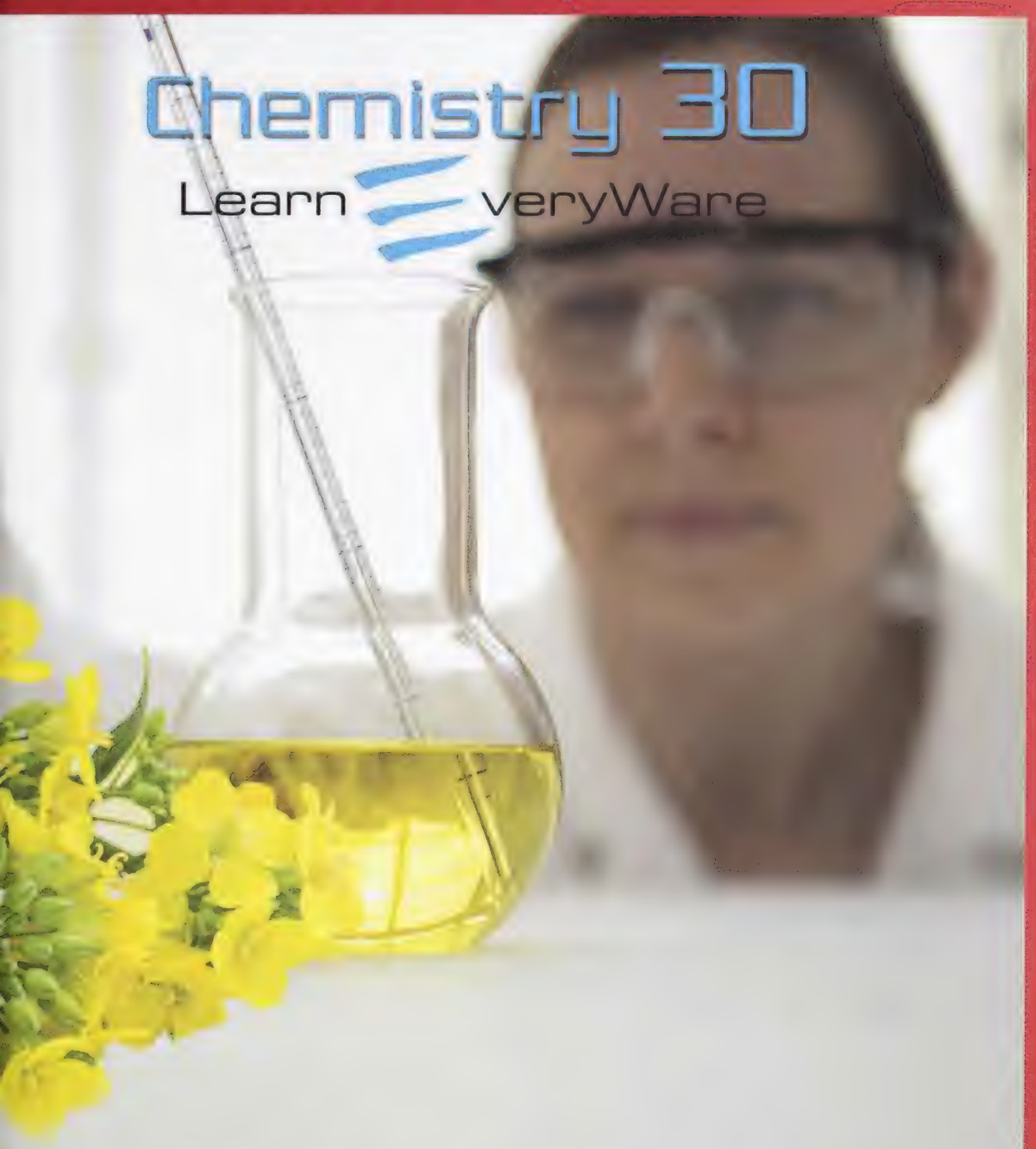
$-4053.6\ kJ - (1\ mol \times \Delta_f H_m^\circ(hexane)) = -4162.9\ kJ$

$\Delta_f H_m^\circ(hexane) = +109.3\ kJ/mol$

The standard molar enthalpy of formation for hexane is +109.3 kJ/mol.

Chemistry 30

Learn EveryWare



Talking Energy

Module 2

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Module 2—Talking Energy

Module Introduction

In Module 2 you will keep investigating energy changes in chemical reactions by focusing on changes that occur at the molecular level.

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You will continue the ecotour planning you began in Module 1 by considering using biodiesel in vehicles required by your ecotour. Biodiesel is an alternative fuel that can be produced from waste cooking or other oils. You will consider the production and use of biodiesel from a variety of perspectives.

In Module 2 you will investigate the following question:

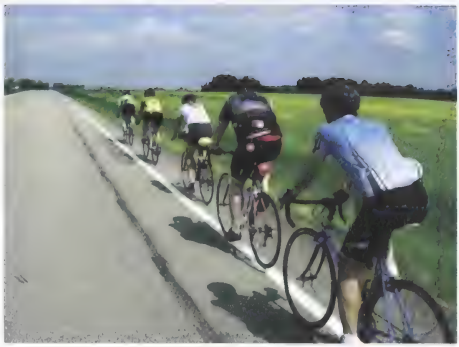
- What energy changes must be considered when designing chemical systems?

You will also continue to address the Module 1 questions:

- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?
- How does society use knowledge of the energy associated with chemical processes to promote sustainability?
- In what ways have issues of energy use affected the development of past and present societies?

Remember that each lesson will also be organized around questions intended to guide your study. As you proceed through Module 2, you may record answers to these questions and any interrelationships that exist between them in a concept map or graphic organizer. More information is available in the Unit A Concept Organizer. In the Module 1 Summary you will receive further information on how you can use your concept map or graphic organizer to review the concepts you studied in this module.

Big Picture



You may have planned that participants in your ecotour will see parts of your local area by cycling. What mode of transportation could be more ecofriendly than cycling—transportation powered by people? However, the cyclists in your ecotour will likely need to be supported by a vehicle. If so, you might consider using a vehicle that uses an environmentally friendly fuel as its energy source.

Biodiesel is one such fuel that has been receiving a great deal of attention. Oil from the canola plants pictured to the right of the cyclists in the photograph can be used to produce biodiesel, as can waste vegetable oil from restaurants.

In Module 2 you will learn more about energy changes in chemical reactions while investigating the production, testing, and use of biodiesel as a possible fuel source for your ecotour.

The use of biodiesel as a vehicle fuel for your ecotour planning will tie into the Module 2 Assessment. Read on to learn more about the lessons, activities, and assessments you will complete as you progress through Module 2.

Assessment in This Module

Each lesson contains a range of activities and assessment options. These include assignments, labs, and Self-Check, Try This, Discuss, Reflect and Connect, and Reflect on the Big Picture activities. Instructions will be provided for each of these activities so that you can appropriately focus your time and effort. Your teacher will tell you which assessment options to complete and which responses to submit for marks or feedback. Remember to save all of your work in your Chemistry 30 folder.

In the Module 2 Assessment you will research biodiesel, and you will use your findings to decide whether to use biodiesel in your ecotour operation. You will develop a presentation for your ecotour clients and others interested in your operation explaining why you will or will not use biodiesel.

You may wish to look at the Module Assessment and the Unit Assessment before starting Lesson 1.

In This Module

Lesson 1—Alternative Fuels: Biodiesel

When running an ecotour you often have to "walk the talk." Using biodiesel where possible may improve your credibility as an ecotour operator. In Lesson 1 you will make and test biodiesel, and you will begin to consider whether you should use biodiesel in your ecotour's operations.

You will investigate the following lesson question:

- What makes a good fuel?

Lesson 2—Energy Diagrams and Activation Energy

In Lesson 2 you will consider the events that occur during a chemical reaction from the molecular level. You will learn about activation energy, and you will integrate this concept into your understanding of enthalpy changes for reactions involving endothermic and exothermic change.

You will investigate the following lesson question:

- Why is energy needed to start an exothermic reaction?

Lesson 3—Catalysts

Catalysts are important components of industrial and biological systems. In Lesson 3 you will learn how catalysts affect the rate of chemical reactions, including the production of biodiesel.

You will investigate the following lesson questions:

- What is a catalyst?
- How does a catalyst influence a chemical reaction?

Module 2—Talking Energy

Lesson 1—Alternative Fuels: Biodiesel

Get Focused

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There is no doubt that your ecotour will involve some sort of travel using vehicles. Whether you will be driving support for the participants when they are cycling or collecting them downstream after river canoeing, you will need to transport people and equipment to and from the unique activities you will offer.

Many ecotours have made the decision to use biodiesel in their vehicles where possible. What is biodiesel and how does its use promote sustainability? In Lesson 1 you will learn about biodiesel. You will begin to evaluate its properties and suitability as a fuel for your ecotour. To assist in your evaluation you will make and test biodiesel.

Consider the following question as you complete Lesson 1:

- What makes a good fuel?

Module 2: Lesson 1 Assignment

In the Lesson 1 Assignment you will complete a virtual investigation in which you will make and test biodiesel. You will be directed to go to the Assignment Booklet to complete the Module 2: Lesson 1 Assignment later in this lesson.

The other questions in this lesson are not marked by the teacher; however, you should still answer these questions. The Self-Check, Try This, and other types of questions are placed in this lesson to help you review important information and build key concepts that may be applied in future lessons. You should record the answers to all the questions in the lesson and place those answers in your course folder.

After a discussion with your teacher, you must decide what to do with the questions that are not part of your assignment. For example, you may decide to submit the responses to Try This and other questions that are not marked to your teacher for informal assessment and feedback. Your answers are very important to your teacher. They provide your teacher with information about your learning, and they help your teacher identify where adjustments to your instruction may be necessary.

Explore

Try This

What makes a good fuel?

TR 1. List as many criteria as you can think of that should be considered in choosing an appropriate fuel for a vehicle. Rank your criteria in order of importance, and then rationalize your ranking.

Save your response in your course folder. You may wish to revise your ranking as you work through Module 2 and learn more about different fuels, including biodiesel.

Read

How many of the criteria you listed in TR 1 relate to the energy content of fuel? In Module 1 you performed a calorimetry experiment to determine the energy content per gram of a nut. You also performed calculations to determine the molar heat of combustion for some hydrocarbons using standard molar enthalpies of formation.

Calorimetry and standard molar enthalpy of formation are two ways to determine the energy change associated with the combustion of a fuel. How are these two methods similar and how are they different? Which means would be most helpful to you when making a decision about using biodiesel as a vehicle fuel? To answer these questions it might be helpful to know what biodiesel is. In the next investigation you will make biodiesel and then test it to determine its energy content.

In preparation for the investigation, complete the following Self-Check questions to review your ability to perform calculations for molar enthalpy of combustion. You may wish to review Module 1, Lesson 5, Self-Check question 1 prior to attempting these questions.

Self-Check

Use the following data to answer the next question:

Fuel	Heat of Combustion (kJ/g)	Chemical Formula
methane	50.01	CH_4
propane	46.36	C_3H_8
octane	44.43	C_8H_{18}

SC 1. Rank the fuels from lowest to highest heat of combustion as expressed in kJ/g in the data table.

SC 2. Explain how you could convert a heat of combustion for the hydrocarbons listed in the data table into a molar enthalpy of combustion.

SC 3. Calculate the molar enthalpy of combustion for each of the fuels listed in the data table. Rank the fuels from lowest to highest molar enthalpy of combustion.

SC 4. Compare the rankings you developed in SC 1 and SC 3.

SC 5. Does a trend exist between the molar enthalpies of combustion and the molar masses of the fuels? (You may wish to refer to the work you completed in SC 3 and SC 4.)

SC 6. List one advantage of communicating the energy change associated with combustion of a hydrocarbon using the units kJ/mol and kJ/g.

Check your work with the answer in the appendix.

Lesson 1 Lab: Biodiesel

Introduction

One of the ways to evaluate biodiesel as a fuel is to prepare some biodiesel and then test it. Biodiesel can be prepared from any vegetable oil or animal fat. A popular choice of oil is waste vegetable oil used in food preparation. In this investigation you will make biodiesel from olive oil.

This lab is in two parts. You will prepare and test biodiesel against the materials used in its preparation to compare their qualitative aspects of combustion. You will also perform an experiment to determine the biodiesel's energy content.

Open the Assignment Booklet. You will record data and complete your analysis in the "Module 2: Lesson 1 Assignment."

If you do not have access to all materials and a supervised laboratory, or if you would like to see the lab performed before you attempt it, go to the course multimedia DVD, and view the following two virtual investigations:

- "Lesson 1 Lab: Part 1—Making Biodiesel"
- "Lesson 1 Lab: Part 2—Testing Biodiesel"

If you will not be completing the lab yourself, remember to record data and observations as you view the presentations.

Background Information

Previous science courses probably taught you that molecules store chemical potential energy, which can be released when chemical bonds in matter are broken and new bonds are formed. Maybe you've even completed an experiment to determine the energy in a sample of food or fuel. Whether oil is crude or plant-based—peanut oil, palm oil, olive oil, or canola oil—it has molecules that are often described as "energy rich."

Rudolf Diesel, the inventor of the diesel engine, demonstrated in 1900 at the World's Fair in Paris that an engine could run on peanut oil rather than on petroleum-based fuels.

Considering the current concern over the depletion of crude oil reserves and the growing demand for energy, Diesel was quite a visionary when he mentioned, in 1912, that

> Even though the use of vegetable oils for engine fuels may seem insignificant today, such oils may become in the course of time as important as the petroleum and coal tar products of the present time.

Diesel's insight about the potential of plant-based oils as an energy source is being demonstrated by people using waste vegetable oil from restaurants as a fuel in their vehicles powered by diesel engines. Around the world, some governments and some corporations within the energy industry are promoting the production of biodiesel, the fuel produced by the modification of vegetable oils.

The yearly consumption of diesel fuel in North America is 245.5 billion litres, most of it for transportation of goods and people. The production and sale of blended diesel fuels, which contain a percentage of biodiesel (e.g., 20% in the case of biodiesel B-20), mixed with petroleum-based diesel fuel, is a growing industry in Europe, where sources of petroleum-diesel are limited. Concerns about depleting petroleum sources elsewhere in the world, including North America, have forced governments and the oil industry to consider biodiesel as a means to offset some of the demand for petroleum-diesel.

In this project, you will investigate the production and use of biodiesel, focusing on the chemistry of its production, the practicality of its use at low temperatures, the energy changes associated with its use, and the sustainability of this energy source.

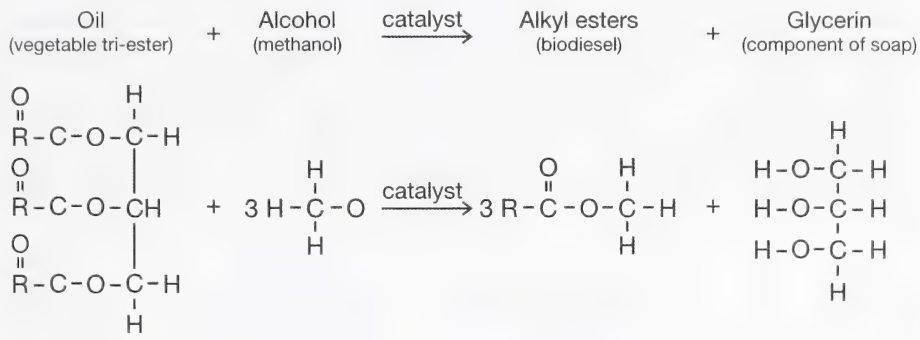
Performing the Lab

Complete the following two investigations, the instructions for which appear one after another directly below:

- Lesson 1 Lab: Part 1—Making Biodiesel
- Lesson 1 Lab: Part 2—Testing Biodiesel

Lesson 1 Lab: Part 1—Making Biodiesel

Biodiesel is an alternative fuel that is made from vegetable and animal oils. It can be used directly in diesel vehicles or blended with traditional petroleum diesel. You will discover during this lab how easy it is to make and store biodiesel. The chemical reaction to produce biodiesel is as follows:



(R represents a hydrocarbon chain that is highly variable in length: 14-24 carbon atoms)

Materials

- lab balance (if using NaOH or KOH base in solid form)
- two 250-mL Erlenmeyer flasks and stoppers
- 100-mL graduated cylinder
- 50-mL graduated cylinder
- disposable pipettes or a turkey baster
- thermometer
- warm water bath (40–60°C)
- 100 mL oil (A different oil for each group is best; possible oils are canola, olive, safflower, lard (warmed to liquid), strained deep fryer oil, grape seed, flaxseed, and sesame.)

  Cautionary note: Avoid nut oils because of potential allergies.

- 20 mL methanol

  Cautionary note: Methanol is flammable, a dangerous fire risk, and toxic by ingestion.

- **ONE** of the following base solutions or solid base crystals: 15 mL of 1.0 mol/L NaOH(aq), 15 mL of 1.0 mol/L KOH(aq), 0.6 g of NaOH(s), 0.9 g of KOH(s)

  Cautionary note: NaOH and KOH solutions and solids are corrosive.

- safety goggles, gloves, and apron

Safety

- You must wear goggles, gloves, and an apron.
- Methanol is flammable and poisonous. Dispose of excess methanol by allowing it to evaporate in a fume hood, or as directed by your teacher.
- The finished product should be stored in a sealed container and away from heat sources.

Procedure

Note: Biodiesel is made using three main components: oil, alcohol, and a base catalyst. This procedure provides a variety of alternative materials that you could use to produce the biodiesel. Your teacher will direct you to which materials you will be using.

Step 1: Measure out 100 mL of oil using a graduated cylinder, and pour the oil into one of the Erlenmeyer flasks.

Step 2: Record observations of colour, viscosity, clarity, and other aspects of the appearance of the starting material (oil).

Step 3: Check that the temperature of the water bath is between 40°C and 65°C. Place the Erlenmeyer flask containing the oil sample into the water bath.

Step 4: While your oil is warming, measure out 20 mL of methanol using a 50-mL graduated cylinder, and pour the methanol into a second Erlenmeyer flask.

Step 5: To the Erlenmeyer flask containing the methanol, add **ONE** of the following: 15 mL of 1.0 mol/L NaOH(aq) solution, 15 mL of KOH(aq) solution, 0.6 g of NaOH(s), or 0.9 g of KOH(s). Swirl your mixture of methanol and base gently to mix. This mixture is called methoxide.

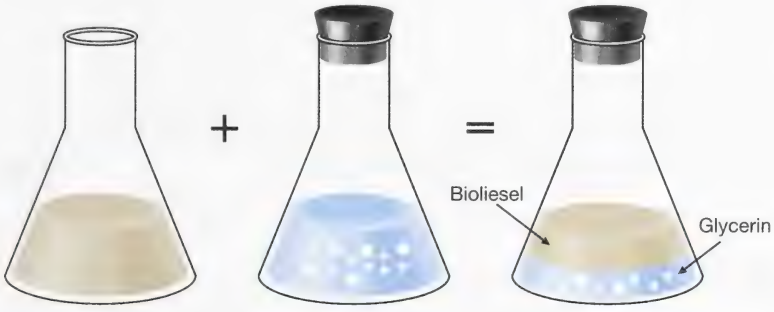
- If using a solid base, the mixture should be swirled or stirred until the solid base dissolves completely.

- To prevent evaporation, this mixture should be stoppered until it is ready to be added to the oil.

Step 6: Pour the methoxide mixture into the warm oil in the Erlenmeyer flask.

Step 7: Stir, swirl, or stopper and gently shake the mixture for several minutes. The mixture will become cloudy and turn a milky colour. A stopper or aluminum foil can be used on the flask to control fumes.

Step 8: If the reaction is successful, you should start seeing two layers developing inside the flask. The heavier glycerin will start to settle to the bottom soon after you stop mixing the reactants. The biodiesel will be in the upper layer. The biodiesel varies in colour depending on the oil used. This will take at least an hour, but longer is better. The mixture should sit overnight to completely react.



Collecting Biodiesel (best completed the next day)

Step 9: Use a disposable pipette or a turkey baster to carefully remove the top layer, containing the biodiesel, from the Erlenmeyer flask and move the biodiesel to a clean graduated cylinder.

Step 10: Record the volume of the biodiesel transferred from the Erlenmeyer flask.

Step 11: Record observations of colour, viscosity, clarity, and other aspects of the appearance of the starting material (oil) and the product (biodiesel) collected.

Step 12: Place the biodiesel into an appropriately labelled container. Ensure that the contents of the container are identified, and add an appropriate WHMIS label, your name, and today's date.

Note: This is crude biodiesel and is **NOT** of a high enough quality to be put directly into a vehicle. In industrial processes, it must go through a process called "washing" to remove excess glycerin, base, and alcohol.

Burning the Biodiesel (your teacher may demonstrate this step)

Step 13: Biodiesel can be safely used in spirit burners. Pour some of your biodiesel into a spirit burner. Once the biodiesel has soaked up the wick, light the wick of the spirit burner. If the biodiesel does not soak up the wick, use the pipette to place a few drops on the wick. Record your observations.

Step 14: Try burning the unreacted oil and the methanol in other spirit burners. For each different fuel tested, record your observations.

Step 15: Store the remainder of the biodiesel in an appropriate container labelled with your name. This may be used for Part 2 of this project.

Lesson 1 Lab: Part 2—Testing Biodiesel (Determining the Energy Content of Biodiesel)

Purpose

In this section you will compare the energy content of the biodiesel created in Part 1 of this investigation with methanol and the oil used in its preparation.

Materials

- three 25 × 200-mm test tubes
- distilled water
- vegetable oil (used as a reactant in Part 1)
- methanol (the alcohol used in Part 1)
- biodiesel (produced from vegetable oil in Part 1)
- three spirit burners
- test-tube clamp and stand
- thermometer and clamp
- safety goggles, gloves, and apron
- 50-mL graduated cylinder
- matches

Procedure

Step 1: Use an electronic balance to measure the mass of three spirit burners containing the following three fuels: vegetable oil, methanol, and biodiesel (prepared in Part 1). Record the mass of each burner in a data table of your own construction.

Step 2: Use a graduated cylinder to measure 30.0 mL of distilled water, and transfer the water to a 25 × 200-mm test tube. Place the test tube in a test-tube clamp attached to a stand. (Note: Use the approximation that 1 mL of water has a mass of 1.0 g.)

Step 3: Position the test tube so that the bottom of the test tube is 2 cm above the wick of the unreacted spirit burner containing the vegetable oil.

Step 4: Use a thermometer to measure the initial temperature of water inside the test tube. Record the initial temperature of the water.

Step 5: Light the wick of the spirit burner and use the flame to heat the bottom of the test tube for 60 seconds.

Step 6: Remove the spirit burner from underneath the test tube, and use the burner lid to extinguish the flame.

Step 7: Use the thermometer to measure the final temperature of the water. Record the temperature.

Step 8: Measure the mass of the spirit burner, and record the value.

Step 9: Repeat Steps 2 through 8 using a new test tube with water and the spirit burner containing the alcohol.

Step 10: Repeat Steps 2 through 8 using a new test tube with water and the spirit burner containing the biodiesel produced in Part 1 of the project.

Module 2: Lesson 1 Assignment

If you have not already done so, open the Assignment Booklet. Complete all of the "Module 2: Lesson 1 Assignment."

Read

In the analysis for the investigation you were asked to calculate an energy of combustion per gram of biodiesel combusted. The biodiesel that you made in the investigation is not a pure substance. The biodiesel contained many products including different organic acids, glycerol, and products of incomplete or side reactions. Can you explain why the mixture of combustible materials in biodiesel makes it impossible to calculate the biodiesel's molar mass and a molar enthalpy for its combustion? Can you think of other examples where it is not possible to calculate an energy content per mole of substance?

Reflect on the Big Picture

Throughout Module 2, Reflect on the Big Picture activities will prepare you for the Module 2 Assessment. In the Module 2 Assessment you will prepare a presentation defending a position on the use of biodiesel by your ecotour company.

In this lesson you completed a virtual investigation in which you prepared biodiesel and tested it to determine its energy of combustion per gram. At the beginning of this lesson you were asked to consider the possible use of biodiesel as a fuel for vehicles used in your ecotour. Does biodiesel measure up?

RBP 1. Begin the process of assessing biodiesel as a fuel. Use the knowledge you gained from this lesson and research you find on the Internet and through other sources to consider the following qualities of biodiesel:

- energy content relative to other fuels
- availability relative to other fuels
- cleanliness of combustion
- ease of preparation

You may wish to consider these qualities from different perspectives as you develop your response. For example, the availability of biodiesel may be seen differently from an ecological or economic perspective as opposed to a scientific one.

You may also use this opportunity to address other factors important to your decision. For example, there may be considerations that are important because of where your tour will operate, the conditions under which it will operate, or specific activities that you have planned.

Save your work in your ecotour planning subfolder. You will consider other aspects of biodiesel use and production, and you will refine and add to your work as you progress through Module 2.

Lesson Summary

In Lesson 1 you considered the following questions:

- What makes a good fuel?

This lesson addressed the criteria and perspectives society uses to make fuel choices. In running an ecotour you often have to "walk the talk." Using biodiesel where possible may improve your credibility as an ecotour operator and may enable you to provide a more sustainable experience for your participants. You prepared and tested biodiesel, and you reflected on the criteria used to decide whether to use biodiesel. This will help you make an appropriate choice of fuel at the end of Module 2.

Module 2—Talking Energy

Lesson 2—Energy Diagrams and Activation Energy

Get Focused

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In Lesson 6 of Module 1 you learned how potential energy diagrams can be used to communicate enthalpy changes. It is common knowledge that you have to provide a spark, a flame, or energy in another form to get most fuels to combust.

In Lesson 1 of Module 2 you observed that some of the fuels being tested in the spirit lighters were much easier to ignite than others. Using potential energy diagrams, how can you demonstrate the energy necessary to initiate a combustion and the difference in the magnitude of energy required for some fuels?

In Lesson 2 you will investigate how energy is involved in initiating chemical change. In order to better evaluate biodiesel as a fuel, it is necessary to understand the factors that affect how easily some fuels ignite. Your investigation in this lesson may also provide insight into the scientific reasoning behind the suggested practice of storing fuels in a cool, dark place.

Consider the following question as you complete Lesson 2:

- Why is energy needed to start an exothermic reaction?

Module 2: Lesson 2 Assignment

There is no assignment for this lesson. However, later in this lesson you will continue your work on the Module 2 Assessment as you collect information about the performance of biodiesel compared to traditional diesel fuel.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

Explore

Read

In previous science courses you learned that chemical reactions occur as a result of colliding particles. To understand why a chemical reaction occurs and what events occur during a reaction, you may have to imagine a reaction in very slow motion.

Read pages 524–526 in the textbook to learn about the events that occur during a chemical reaction.

Self-Check

SC 1. Complete "Practice" questions 1–3 on page 526 of the textbook.

Check your work with the answer in the appendix.

Read

So what does a spark really do in terms of starting a combustion reaction? In the previous section you learned that molecules must collide with sufficient energy to cause a reaction. From where do the molecules get that energy?

As you may have suspected, energy to initiate a combustion reaction can come from a spark, the flame from a match, or, in the case of a spontaneous combustion, from the heat of a hot day. Read the section "Activation Energy of a Reaction" on pages 526–530 in the textbook to learn more about the energy required to initiate a reaction.

Try This

Answer the following question in which you will interpret and apply your textbook reading.

TR 1. It is a common observation that vapourized hydrocarbons combust more readily than liquid hydrocarbons. Use a potential energy diagram to compare the potential energy of a vapourized hydrocarbon to the potential energy of the same hydrocarbon in the liquid phase. In addition, use the difference in potential energy between the two phases to explain this observation and how it relates to energy of activation within a chemical system.

Save your response in your course folder and submit a copy to your teacher.

Self-Check

SC 2. Complete "Practice" questions 2–6 on page 531.

SC 3. Complete "Section 12.2" questions 1–3 on page 534. After completing the questions, ask yourself the following question: Is activation energy only required to initiate an exothermic reaction like a combustion of a hydrocarbon?

Check your work with the answer in the appendix.

Reflect on the Big Picture

In Module 2, Reflect on the Big Picture will prepare you for the Module 2 Assessment in which you will prepare a presentation defending a position on the use of biodiesel by your ecotour company.

In the previous lesson you saw that biodiesel requires more effort to light compared to methanol. Since biodiesel is a mixture of molecules, it is difficult to make conclusions about its activation energy relative to other hydrocarbons.

In your investigation about the performance of biodiesel you may have already found that biodiesel performs very similarly to diesel fuel in terms of engine operation and fuel economy. Is this true at all temperatures? If your ecotour involves winter activities, will using biodiesel present a problem?

Research how biodiesel performs compared to conventional diesel fuel and how biodiesel performs at temperatures similar to those you will encounter when operating your ecotour. Remember to consider the qualities you researched in Lesson 1 as you compare the two fuels.

Save your notes in your ecotour planning sub-folder. Remember to collect information that is accurate (correct) and reliable (consistent with the results from other or repeated tests). You will be required to use the information you collect to support your position on the use of biodiesel, so it is important to consider the source and the number of sources from which you collect your information. Remember that you will refine and add to your research as you progress through Module 2.

Lesson Summary

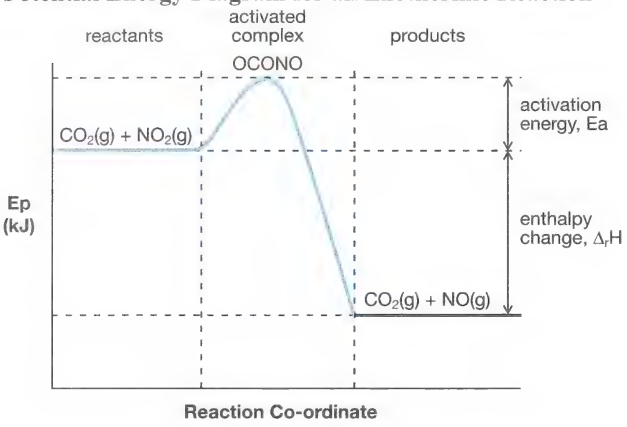
In Lesson 2 you considered the following question:

- Why is energy needed to start an exothermic reaction?

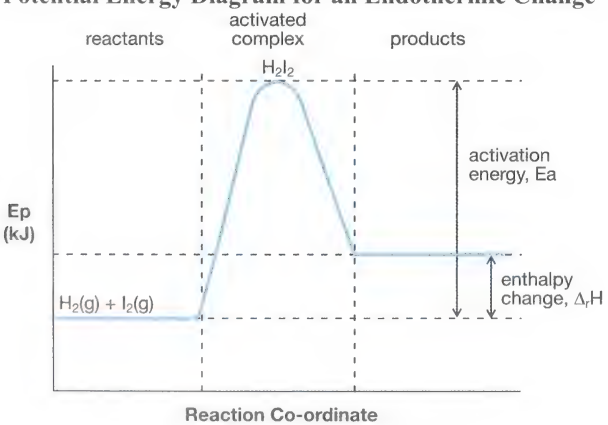
You learned about activation energy and the events that occur during a chemical reaction. You learned that certain conditions, including sufficient particle speed and orientation, are necessary for a reaction to proceed. Energy of activation is a threshold that, once met, allows molecules to collide with sufficient energy to react.

In this lesson you also learned how the concept of activation energy integrates into your understanding of enthalpy changes for both endothermic and exothermic changes in chemical reactions. Finally you learned how to view enthalpy changes as a change in the bond energies between reactant and product particles.

Potential Energy Diagram for an Exothermic Reaction



Potential Energy Diagram for an Endothermic Change

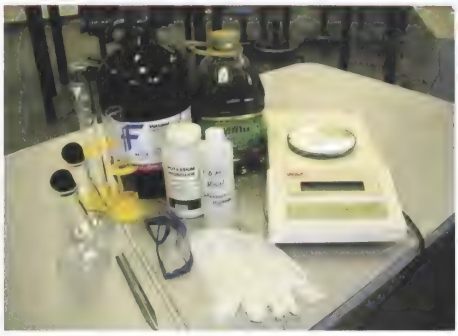


In the next lesson you will further your understanding of activation energy and its impact on chemical processes as you learn about catalysts. You will apply your understanding of catalysts as you further assess the production of biodiesel through a chemical reaction in which sodium hydroxide is used as a catalyst.

Module 2—Talking Energy

Lesson 3—Catalysts

Get Focused



As you researched the performance of biodiesel in the previous lesson, did you come across personal accounts from people who have been making and using biodiesel in their own automobiles? You probably came across information that identifies the importance of using a strong base—a hydroxide—when preparing biodiesel. Why is sodium hydroxide, or alternatively potassium hydroxide, essential to making biodiesel? As you will learn in this lesson, these compounds act as catalysts in the chemical reaction that produces biodiesel. Catalysts are the focus of this lesson.

Consider the following questions as you complete Lesson 3:

- What is a catalyst?
- How does a catalyst influence a chemical reaction?

Module 2: Lesson 3 Assignment

In the Lesson 3 assignment you will design a laboratory investigation to compare catalysts used in the preparation of biodiesel. You will be directed to go to the Assignment Booklet to complete the Module 2: Lesson 3 Assignment later in this lesson. You will also continue your work on the Module 2 Assessment by completing a Reflect on the Big Picture exercise.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

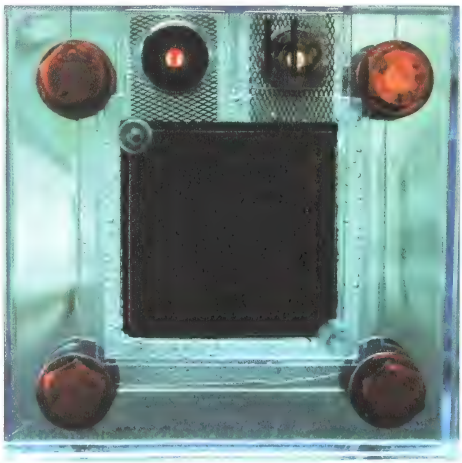
Explore

Read

In the previous lesson you learned about activation energy, the energy required to initiate a chemical reaction. You considered the combustion of hydrocarbons and the energy required to "activate" molecules. You learned that once the reacting particles have reached the necessary activation energy, the chemical reaction, in this case a combustion reaction, can occur.

In Module 2 Lessons 1 and 2, you learned that molecules need to have sufficient energy and must collide in the correct orientation in order for the bond between atoms in the reactants to be broken and for new bonds to form. For some chemical reactions, the energy required to initiate chemical change can be quite high. As you learned in Lesson 1, reactions with higher activation energies tend to occur more slowly. If you are depending on a reaction, and need it to occur quickly, how can you overcome the problem of a high activation energy slowing your reaction rate?

You may have learned about fuel cells in previous science courses. Many fuel cells appear to use a reaction that looks like a combustion reaction. For example, the hydrogen-oxygen fuel cell used in the space program relies on the reaction
$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$.



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This reaction is also the basis for a hydrogen "pop" test you may have performed in previous science courses. When performing a hydrogen pop test, a burning splint is placed into a test tube containing a small quantity of hydrogen gas. As you learned earlier, the flame serves as a source of energy. The energy helps the reactants achieve the activation energy required for the reactants to engage in collision and form the products of the reaction.

In the space program hydrogen and oxygen are the reactants in a fuel cell—a device that converts chemical potential energy into electrical energy. The electricity produced by the fuel cells in a spacecraft run all the major systems inside the spacecraft including lighting, communication, and life support. Due to the risk of explosion, the reaction between hydrogen and oxygen cannot involve a spark flame, but it still requires an input of energy to proceed. How can this be done without a flame?

catalyst: a substance that reduces the energy necessary to start a chemical reaction

Catalysts are substances that increase the rate of a chemical process but are not consumed during the process.

Look at the fuel cell pictured. You will see a membrane in the middle of the cell. The chemical reaction between hydrogen and oxygen in the fuel cell occurs on this membrane. Using a structure like this allows the reaction between hydrogen and oxygen to occur without the need for any more energy than the gases already have at room temperature. Since the membrane in a fuel cell allows the reaction between hydrogen and oxygen to occur with a lower activation energy, the membrane acts as a **catalyst**.

A catalyst is something within a chemical system that lowers the activation energy required for a reaction to occur by allowing an alternate path for the reaction. This last point is very well demonstrated by the fuel cell membrane, since the membrane acts to physically separate the hydrogen and oxygen gases, meaning they never actually collide with one another. By using a catalyst, a different mechanism for the reaction occurs, and the product $H_2O(l)$ is made.

Many industrial processes, including the production of biodiesel, involve the use of catalysts. In industrial settings catalysts are often used because they increase the rate (speed) of a reaction without being consumed in the overall process. Often, they also allow a reaction to occur at a lower temperature than would otherwise be possible.

Read pages 535–538 in the textbook. Stop reading when you get to the section "Catalysts and the Nature of Science." As you read this section, pay special attention to the explanation of how a catalyst affects the changes to the potential energy in a chemical system as a reaction occurs.

Self-Check

SC 1. Complete "Practice" questions 1–4 on page 535 of the textbook.

Check your work with the answer in the appendix.

Read

You might wonder how catalysts are able to reduce the activation energy, which increases the rate of a chemical reaction, and still not be consumed in the process. Read the section "Theoretical Explanation of Catalysts" on pages 536–538 in the textbook.

The effect catalysts have on chemical systems is of great importance to many industries. Read the sections "Catalysts and the Nature of Science" and "Uses of Catalysts" on page 538–541 in the textbook.

Try This

TR 1. Read the four points made in the "Summary" section on page 541 of the textbook. For each of the four points listed, provide some elaboration explaining why each of these statements made about catalysts is true. You may choose to provide an explanation or an example from the textbook or these course materials in a written, audio, or some other format.

Post a copy of your response to TR 1 to the discussion area for your class. Read the responses of at least two other students. Provide feedback to the students on their responses to help them ensure that their understanding of catalysts and their action is clear and thorough. Revise your response based on the feedback you receive. Save a copy of your revised response in your course folder.

Self-Check

SC 2. Complete "Section 12.3" questions 1–6 and 9 on page 542 of the textbook.

SC 3. In addition to completing the "Section 12.3" questions listed above, explain how your answers to these questions will help you determine the desirability of burning biodiesel as a fuel.

Check your work with the answer in the appendix.

Reflect and Connect

There is no doubt that you would use a catalyst if you were to make biodiesel. The procedure you followed in Lesson 1 indicated that either sodium hydroxide or potassium hydroxide could be used. Does it matter which one of these you use?

Module 2: Lesson 3 Assignment

Go to the Assignment Booklet, and complete "Module 2: Lesson 3 Assignment."

Reflect on the Big Picture

In Module 2, Reflect on the Big Picture will prepare you for the Module 2 Assessment in which you will prepare a presentation defending a position on the use of biodiesel by your ecotour company.

So far in this module you have collected information about the following qualities:

- energy content of biodiesel relative to other fuels
- availability of biodiesel relative to other fuels
- cleanliness of biodiesel when combused (emissions testing)
- ease of preparation of biodiesel
- performance of biodiesel under weather conditions in the area in which your ecotour will occur

The final quality you will consider is the catalyst used in the preparation of biodiesel.

RBP 1. Consider the chemical properties of sodium hydroxide or potassium hydroxide, and collect information about the cost and environmental issues related to using these as catalysts to prepare biodiesel. Identify safety issues that you would need to attend to when preparing or using biodiesel.

Save your research in your ecotour planning sub-folder. After you complete this lesson, proceed to the Module 2 Summary and Assessment where you will use the information you have collected to complete the Module 2 Assessment.

Lesson Summary

In Lesson 3 you considered the following questions:

- What is a catalyst?
- How does a catalyst influence a chemical reaction?

Catalysts are important components of industrial and biological systems. The use of catalysts increases the rate at which a reaction occurs, thus allowing for the more rapid production of products. In this lesson you saw how catalysts allow unique chemical systems like fuel cells and petroleum cracking to occur with significantly reduced energy input. You also evaluated the use of a catalyst in the production of biodiesel from more perspectives than just efficiency and rate of reaction. You considered cost of production, environmental aspects, and safety concerns.

Module 2—Talking Energy

Module Summary

This module completes your study of thermochemical changes that began in Module 1.

You considered the following module questions, some of which you began to examine in Module 1:

- What energy changes must be considered when designing chemical systems?
- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?
- How does society use knowledge of the energy associated with chemical processes to promote sustainability?
- In what ways have issues of energy use affected the development of past and present societies?

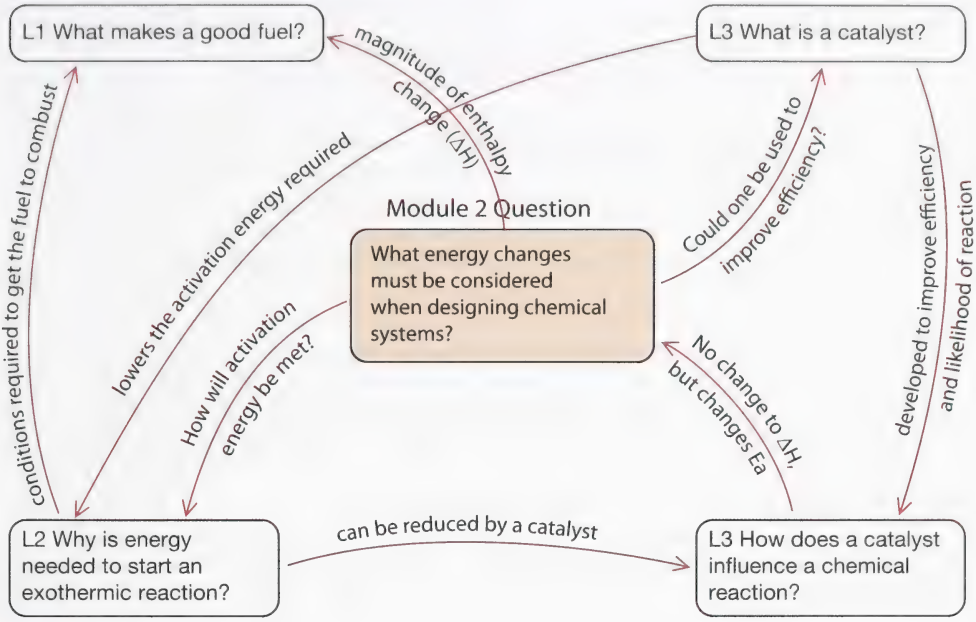
In Module 2 you investigated energy changes in chemical reactions by focusing on changes that occur at the molecular level. You learned about activation energy and its role in every chemical reaction, and you learned about the conditions necessary for molecules to participate in a chemical reaction. You also learned about catalysts and their ability to lower activation energy and thereby increase the rate of a chemical reaction.

You completed a virtual investigation in which you made and tested biodiesel, and you researched biodiesel's use as a vehicle fuel for your ecotour. The information you learned in Module 2 will provide a foundation for your learning in other units of this course, especially in Unit D where you will investigate equilibrium of chemical systems.

Concept Map or Graphic Organizer

As you worked through Module 2, you may have added information to a concept map or graphic organizer based on the module and lesson questions listed in the Module 2 Concept Organizer. Now is a good time to review the relationships in your concept map or graphic organizer and to try to answer the module and lesson questions.

The sample Module 2 concept map shown below provides one set of possible links between the questions. Remember that this is one possible description only—there are many other correct possibilities. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or to compare your map or organizer with those of other students in your class. This will ensure that your interpretations of lesson materials and your descriptions are accurate.



Module Assessment

Evaluating the Use of Biodiesel in Your Ecotour

In this module you were asked to consider the use of biodiesel as a vehicle fuel in your ecotour. Does biodiesel measure up? Undertake an assessment based on the following qualities:

- energy content relative to other fuels
- availability relative to other fuels
- cleanliness of combustion
- ease of preparation
- performance under weather conditions such as those in which your ecotour will operate

- cost, safety, and environmental issues related to the use of a catalyst in the preparation of biodiesel

You may wish to consider these qualities from different perspectives as you develop your response. For example, the availability of biodiesel may be seen differently from an ecological or economic perspective than from a scientific viewpoint.

You may also wish to address other factors important to your decision. For example, there may be considerations that are important because of where your tour will operate, the conditions under which it will operate, or specific activities that you have planned.

Your response should be a persuasive argument. Think of questions that partners or investors in your ecotour might ask. Work answers to these questions into your presentation. To identify your tour's fuel needs and some of the questions you should address, review all of the information in your ecotour planning sub-folder, including the information you collected in Module 1. Remember to include the sources of your information in your presentation.

Select a means to convey your message that you feel will be most suitable to your goals and audience. This may be as text (in the form of a brochure) or in a multimedia format such as an audio, video, or slide presentation. This is your chance to capture the attention of people interested in your ecotour and to demonstrate how you are able to apply your knowledge of chemical energetics and ecology to your ecotour planning.

Post a copy of your presentation to the discussion area for your class. Review the presentations of at least two other students. Provide feedback to the students to help them improve their presentations. You may choose to revise your presentation based on the feedback you receive from your classmates. Save a copy of your revised response in your course folder.

Consider the criteria and descriptions in the scoring guide below as you develop and revise your presentation. Your teacher will use these same criteria to assess the work you submit. Save the final version of your presentation in your course folder and submit a copy to your teacher for assessment.

Your Module 2 Assessment will also form part of your Unit A Assessment. Please see the Unit A Assessment for more information.

Score	Scoring Description
4 Standard of Excellence	The response is **well organized** and addresses **all** the major points of the question using **effective**, **appropriate**, **and clear** communication strategies. The interrelationships between science, technology, and society are **thoroughly understood**. Risks and benefits of biodiesel preparation and use are **thoroughly evaluated**. Descriptions, explanations, and/or interrelationships between the concepts provided are **correct** and **reflect a thorough understanding** of the use of biodiesel. **Insightful** and **convincing** arguments are used to support a decision or judgment, and **a range of perspectives is considered**.
3	The response is **organized** and addresses **most** major points of the question using **effective**, **appropriate**, **and clear** communication strategies. The interrelationships between science, technology, and society are **understood**. Risks and benefits of biodiesel preparation and use are **evaluated**. Descriptions, explanations, and/or interrelationships between the concepts provided are **correct** and **reflect an understanding** of the use of biodiesel. **Clear** and **logical** arguments are used to support a decision or judgment, and **alternative perspectives are considered**.
2 Acceptable Standard	The response is **generally organized** and addresses **most** of the major points of the question using **adequate** communication strategies. The interrelationships between science, technology, and society are **generally understood**. Risks and benefits of biodiesel preparation and use are **listed**. Descriptions between the concepts provided are **generally correct** and **reflect an adequate understanding** of the use of biodiesel. **Logical** arguments are used to support a decision or judgment, and **perspectives are considered**.
1	The response is **poorly organized** and addresses **few** major points of the question. The interrelationships between science, technology, and society are **poorly understood**. **Few** risks and benefits of biodiesel preparation and use are **listed**. Descriptions, explanations, and/or interrelationships between the concepts provided are **incorrect** and **reflect a poor understanding** of the use of biodiesel. **Poorly formed** arguments are used to support a decision or judgment, and **only one point of view is considered**.
0	The response does not address any of the major points of the question at an appropriate level for a 30-level course.

Module 2 Glossary

catalyst: a substance that reduces the energy necessary to start a chemical reaction

Catalysts are substances that increase the rate of a chemical process but are not consumed during the process.

Unit A Conclusion

In Unit A you learned about thermochemical changes. When matter undergoes physical or chemical changes, energy changes also occur. These energy changes can often be quantified and studied.

In Module 1 you learned about calorimetry. You used a calorimeter in an experiment to determine the energy content of different fuels, including biodiesel.

Studying energy change is an important component of understanding chemical change, since the events occur simultaneously. By quantifying energy changes you gained a greater insight into the characteristics of chemical bonding, including enthalpy changes and chemical bond energies.

In Module 2 you investigated the events and energy changes associated with chemical reactions from the molecular level. You learned about activation energy and the role that catalysts play in chemical processes, including the function of catalysts from the perspective of chemical energetics.

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Throughout Unit A you investigated chemical energetics in the context of designing and testing materials to be used in an ecotour in your local area. In Module 1 you designed the type of tour you would like to provide to visitors to your area, and you investigated questions that influence the food and equipment to be used in your tour. In Module 2 you investigated the use of biodiesel as a vehicle fuel for your ecotour operations.

In this unit you investigated the following module questions:

- Should energy be given a higher priority when making decisions about society's future?
- How does society use the energy of chemical changes?
- What are the impacts of energy use on the environment?

- How does society use knowledge of the energy associated with chemical process to promote sustainability?

- In what ways have issues of energy use affected the development of past and present societies?

- What energy changes must be considered when designing chemical systems?

You should now be able to

- determine and interpret energy changes in chemical reactions
- explain and communicate energy changes in chemical reactions

Self-Check

Go to the course multimedia DVD, and complete the "Unit A Diagnostic Self-Check" to review the concepts, skills, and knowledge introduced and to assess your understanding of them.

If you have trouble answering any of the questions, try one or more of the following options:

- Go to the lesson(s) indicated for each question. Once there, review the information provided and the relevant sections of the textbook.

- View the hint associated with each question.

- Look at the answer and then work backward to understand the problem and its solution.

- Ask your teacher for help.

You understand how important it is to review material in preparation for any tests your teacher may give you and in solidifying your understanding of new concepts. Completing these questions is just one part of your review. Program of Studies information is associated with each question. You may wish to use this information to identify areas in which you need to pay particular attention. You may also answer the questions that appear at the end of each chapter and unit in the textbook.

You have already reviewed your Modules 1 and 2 concept maps or graphic organizers. Now is a good time to give them another look and add any new connections or ideas to them.

Unit Assessment

The Unit A assessment consists of two parts:

- Module 1 Assessment—Ecotour Operations Plan
- Module 2 Assessment—Evaluating the Use of Biodiesel in Your Ecotour

You have already completed both of these assessment activities. Together, these activities provide you with a solid idea of the scientific and other principles associated with showcasing the unique aspects of you local area in a sustainable manner.

For specific information about either part of the Unit Assessment, refer to the Module Assessment for each module.

Appendix

Module 2 Self-Check Answers

Contact your teacher if your answers vary significantly from the answers provided here.

Lesson 1

SC 1. ranking: octane, propane, methane

SC 2. To convert from kJ/g to kJ/mol, multiply the heat of combustion by the molar mass of the hydrocarbon. For example

–50.00 kJ/g × 16.05 g/mol = –802.5 kJ/mol
–46.34 kJ/g × 44.11 g = –2043.9 kJ/mol
–44.408 kJ/g × 114.26 g = –5074.1 kJ/mol

SC 3.

methane: $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$

$$\begin{aligned}\Delta_c H^\circ &= \left[1\text{ mol}(-393.5\text{ kJ/mol}) + 2\text{ mol}(-241.8\text{ kJ/mol})\right] \\ &\quad -\left[1\text{ mol}(-74.6\text{ kJ/mol}) + 2\text{ mol}(0\text{ kJ/mol})\right] \\ &= -802.5\text{ kJ}\end{aligned}$$

$$\begin{aligned}\Delta_c H^\circ &= -802.5\text{ kJ}/1\text{ mol}_{\text{methane}} \\ &= -802.5\text{ kJ/mol}\end{aligned}$$

propane: $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$

$$\begin{aligned}\Delta_c H^\circ &= \left[3\text{ mol}(-393.5\text{ kJ/mol}) + 4\text{ mol}(-241.8\text{ kJ/mol})\right] \\ &\quad -\left[1\text{ mol}(-103.8\text{ kJ/mol}) + 5\text{ mol}(0\text{ kJ/mol})\right] \\ &= -2043.9\text{ kJ}\end{aligned}$$

$$\begin{aligned}\Delta_c H^\circ &= -2043.9\text{ kJ}/1\text{ mol}_{\text{propane}} \\ &= -2043.9\text{ kJ/mol}\end{aligned}$$

octane: $C_8H_{18}(g) + 12.5\ O_2(g) \rightarrow 8\ CO_2(g) + 9\ H_2O(g)$

$$\begin{aligned}\Delta_c H^\circ &= [8\ \text{mol}(-393.5\ \text{kJ/mol}) + 9\ \text{mol}(-241.8\ \text{kJ/mol})] \\ &\quad - [1\ \text{mol}(-250.1\ \text{kJ/mol}) + 12.5\ \text{mol}(0\ \text{kJ/mol})] \\ &= -5074.1\ \text{kJ}\end{aligned}$$

$$\begin{aligned}\Delta_c H^\circ &= -5074.1\ \text{kJ}/1\ \text{mol}_{\text{octane}} \\ &= -5074.1\ \text{kJ/mol}\end{aligned}$$

ranking: methane, propane, octane

SC 4. For the hydrocarbons being compared, the rankings are reversed between the lists. The hydrocarbon with the highest heat of combustion has the lowest molar heat of combustion.

SC 5.

Hydrocarbon	Molar Enthalpy of Combustion (kJ/mol)	Molar Mass (g/mol)
methane, CH_4	–802.5	16.05
propane, C_3H_8	–2043.9	44.11
octane, C_8H_{18}	–5074.1	114.26

Trend: As the molar mass of a hydrocarbon increases, so does its molar enthalpy of combustion.

SC 6. Fuels are usually not sold or distributed by the mole. Volume or mass of a fuel is measurable. An energy value per unit mass can be easily used in predicting net energy output from a selected mass.

Molar energy changes are convenient because they provide insight into the energy associated with a defined number of fuel particles (one mole). When expressed per unit of mass, the number of reacting particles can be different.

Lesson 2

SC 1.

Practice 1.

The molecules must have sufficient energy and be in the proper orientation when they collide. If these two conditions are met, a reaction can occur.

Practice 2.

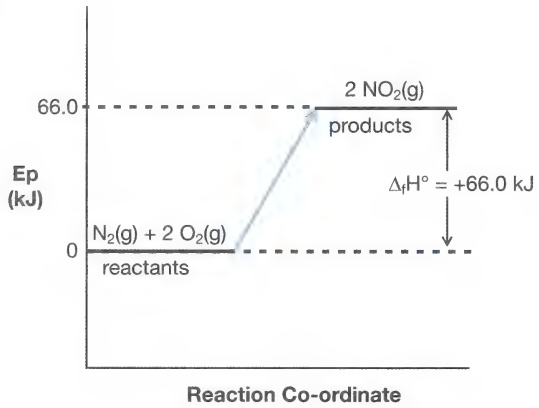
Scientific: A better understanding of how chemical reactions occur might improve the ability to predict when chemical reactions might occur, including the effect that catalysts and other substances have on the progress of a reaction.

Technological: A better understanding of how chemical reactions occur may lead to the development of new processes that improve efficiency or reduce the generation of by-products.

Practice 3.

a. $N_2(g) + 2\ O_2(g) \rightarrow 2\ NO_2(g)\ \Delta_f H^\circ = +66.4$ kJ

b.



c. Answers may vary. The following hypotheses are possible answers:

- The electrons or electrical field in the area of a lightning strike provide conditions that are favourable to initiating the reaction.
- Electrons from the lightning may act as a catalyst.
- Electrons or the electrical field from the lightning may ionize surrounding particles, allowing them to become catalysts in the chemical reaction between nitrogen and oxygen.

SC 2.

Practice 2.

The hypothesis that reactions have an activation energy is suggested by experiments that show energy may be required to initiate a reaction, even if the reaction is self-sustaining once started. An example would be combustion of hydrogen. Also, the fact that similar reactions occur at different rates suggests that the reason for the difference in reaction rates may be differing activation energies. The reactions of alkali metals with water illustrate this. Furthermore, if there were no activation energies, then spontaneous reactions would all occur almost instantaneously. In addition, experiments demonstrating the effect of catalysts are readily explained by hypothesizing the existence of an activation energy.

Practice 3.

a. The reaction is endothermic.

b. (i) represents the activation energy of the forward reaction and (ii) represents the enthalpy change for the reaction.

c. As the reactant molecules approach each other, their combined kinetic energy is at a maximum and the relative potential energy is at a minimum. As they collide and "climb" the energy barrier, kinetic energy is converted to potential energy. Provided they have enough kinetic energy in the first place, they will surmount the barrier. At the top of the energy profile, the potential energy of the system will be at a maximum and the kinetic energy will be at a minimum. At the end of the reaction the system will have less kinetic and more potential energy than it did originally.

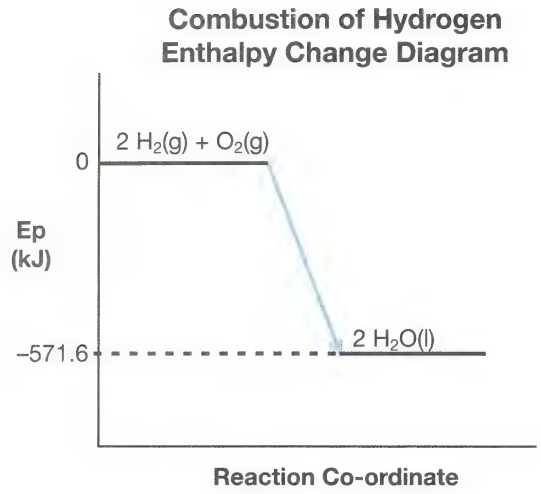
Practice 4.

They differ in that the enthalpy change is the net difference in potential energy between reactants and products, whereas the activation energy is the height of the energy barrier that must be surmounted to achieve a successful collision. They are similar in that each is a difference in potential energy. In the case of the activation energy, it is the difference in potential energy between the reactants and the activated complex rather than between reactants and products.

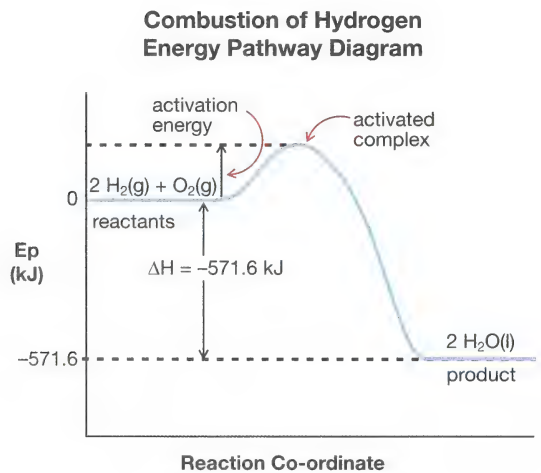
Practice 5.

a. There must be an adequate supply of oxygen to burn the hydrogen, and the reaction needs to be initiated by a spark or flame to overcome the activation energy.

b.



c. and d.



Practice 6.

Purpose

The purpose of this investigation is to test the hypothesis that the activation energy decreases from sodium to cesium.

Problem

What evidence is there that from sodium to cesium, there is a decrease in the activation energy for the reaction with water? The manipulating variable is the alkali metal used, and the responding variable is the observed reaction rate.

Hypothesis

For the reaction with water, the activation energy from sodium to cesium decreases. If the metal reacts more violently with water, then the reaction has a lower activation energy.

Design

Separate small samples of sodium, potassium, and cesium with equal masses will be dropped into water. Evidence of differences in reaction rate will be observed.

Prediction

Cesium will react the fastest and sodium the slowest, indicating that the activation energy decreases from sodium to cesium.

Materials

- sodium
- potassium
- cesium
- 250-mL beakers (3)
- water
- safety screen
- knife
- protective eyewear
- lab apron
- rubber gloves
- paper towels
- 100-mL graduated cylinder
- tweezers

CAUTION

Wear eye protection, apron, and gloves throughout the procedure, and only combine the reactants behind a safety screen.

Procedure

Step 1: Measure 100 mL of water into a 250-mL beaker, and place the beaker behind a safety screen.

Step 2: Using the knife, cut a small piece of sodium (half the size of a small raisin) and remove it from the container in which it was being stored under oil. Place the piece on a paper towel to remove excess oil. Quickly measure the mass of the sodium, ensuring it is 0.50 g.

Step 3: Grasp the sodium with tweezers and dab it with paper towel to remove some oil.

Step 4: Quickly reach around the screen and drop the piece of sodium into the beaker of water.

Step 5: Record evidence for reaction with particular attention to the rate.

Step 6: Repeat Steps 1 to 5 for potassium and cesium.

Step 7: Dispose of the reaction mixtures down the drain.

SC 3.

Section 12.2 1.

Bond energy is the energy required to break a chemical bond, and it is the energy released when a chemical bond is formed.

Section 12.2 2.

In the reactant molecules, if the bonds that are being broken are strong, the activation energy is likely to be high. If the bonds being broken are weak, it is likely that the activation energy will be relatively low.

Section 12.2 3.

By definition, a chemical reaction involves a rearrangement of bonds to produce new substances in which atoms are conserved but the bonding is different. This can only happen if at least some bonds are broken and new ones are formed. For example, in the decomposition of water, O-H bonds are broken and H-H and O=O bonds are formed.

Lesson 3

SC 1.

Practice 1.

Development of catalysts has primarily occurred using empirical knowledge involving investigations that appear to try conditions and identify changes needed to improve the reaction rate.

Practice 2.

The catalytic converter and catalytic cracking towers in petroleum refining are examples of technological inventions that involved the use of catalysts.

Practice 3.

Photosynthesis, fermentation, and cellular respiration are natural (biological) processes that involve the use of catalysts. Many other examples exist as most biological reactions involve the use of enzymes as a catalyst.

Practice 4.

Since enzymes are a type of catalyst they are not changed by the chemical reaction. Since enzymes catalyze many reactions, they do not have to be present in large numbers to improve the efficiency of a chemical process in the body. If poisoned, the reaction rate will be dramatically affected since very few enzyme molecules exist. The resulting rate of reaction will be dramatically reduced due to fewer catalyzed reactions.

SC 2.

Section 12.3 1.

Same: the reactants, products, potential energy (position of reactants and products on a potential energy diagram), overall enthalpy change

Different: activation energy, rate (speed) of reaction, reaction intermediates, activated complex that occurs during the reaction

Section 12.3 2.

a. C and D
b. A, B, and E
c. F
d. $2\ A + B + E \rightarrow F$

Section 12.3 3.

a. The activation energy for the forward reaction is 60 kJ.
b. The activation energy for the reverse reaction is 95 kJ.
c. The enthalpy change for the forward reaction is −35 kJ.
d. The enthalpy change for the reverse reaction is +35 kJ.
e. The forward reaction is exothermic.

Section 12.3 4.

If only 55 kJ of kinetic energy were available, the reactant molecules would rebound without reacting successfully.

Section 12.3 5.

In the reverse direction, a collision with kinetic energy equivalent to 55 kJ would also result in rebound and an unsuccessful reaction.

Section 12.3 6.

The following are examples of catalysts providing solutions to technological problems:

- The catalytic converter in a vehicle's exhaust system reduces air pollution by catalyzing the reduction of NO(g) and NO_2(g) to harmless N_2(g).
- Catalysts are used in the refining of petroleum to increase production of the more desirable fractions by catalytic reforming or alkylation.
- In the upgrading of bitumen to synthetic crude, catalysts are employed during the hydrocracking and hydrotreating processes.
- In the brewing industry, the enzyme in yeast is used in the conversion by fermentation of sugar to ethanol.

Section 12.3 9.

Risks

- Burning fossil fuels is the biggest contributor to global warming through the dramatic increase in CO_2 levels in the atmosphere.
- Fossil fuels are non-renewable, so the world will eventually face shortages.
- The crude oil could be put to better use making petrochemicals instead of being burnt.

Benefits

- Crude oil continues to be less expensive than other sources of energy.
- Canada has a secure supply of crude oil and bitumen for the foreseeable future.
- Crude oil is the most practical and convenient source of liquid fuels for vehicles.

SC 3. To determine the desirability of burning biodiesel it may be necessary to consider the activation energy of its components, as this may help determine biodiesel's ease of combustion. Biodiesel is a renewable energy source if it comes from plant sources; using biodiesel as an energy source will not have the same adverse effects as using fossil fuels.

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